DIVISION V
SECTION 5600
STORM DRAINAGE SYSTEMS & FACILITIES

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5600

PREAMBLE

5600 PREAMBLE

Mid-America Regional Council & American Public Works Association

XX June 2025

To whom it may concern,

This latest version of the KC Metro Chapter of APWA, Section 5600, has been updated to provide the latest state of the practice in stormwater management that addresses both stormwater drainage (quantity) and stormwater quality. This effort was the result of recommendations provided by a 23-person Sustainable Stormwater Task Force that was formed by the KC Metro Chapter Executive Committee in December 2019 and concluded in August 2020. This task force determined that the existing stormwater design criteria did not provide sufficient details and requirements to address the stormwater issues facing the region, including:

1. Urban flash flooding
2. Rapid and severe stream erosion
3. Water quality issues
4. Less than effective detention and green infrastructure designs
5. Inconsistencies in design submittals and requirements

Vision for Resilient Watersheds

Stormwater resiliency is defined as the ability of a community, system, or infrastructure to effectively manage, adapt to, and recover from stormwater-related challenges, such as heavy rainfall, flooding, and runoff. It involves designing and implementing strategies to mitigate the impacts of extreme weather events and climate change, so that stormwater systems—like drainage networks, green infrastructure, and detention basins—can handle current and future water volumes without significant disruption or damage to downstream communities.

Key components of stormwater resiliency include:

Flood Mitigation	**Green Infrastructure**	**Climate Adaptation**	**Ecosystem Protection**	**Community Preparedness**
Reducing flood risks through infrastructure and natural solutions.	Using methods that mimic natural hydrologic processes like rain gardens, permeable pavements, and wetlands to absorb runoff.	Planning for more intense rainfall patterns due to climate change.	Preventing water pollution, protecting natural areas, and improving overall watershed health that may be impacted from excess runoff.	Engaging residents, businesses, and local governments in stormwater planning efforts.

Stormwater Impacts to Other Public Infrastructure

Urban Flash Flooding

Stream Erosion

Water Quality Impacts

SUSTAINABLE STORMWATER TASK FORCE SUMMARY

VISION STATEMENT: RESILIENT STORMWATER MANAGEMENT USES A SUSTAINABLE WATERSHED MANAGEMENT APPROACH THAT **MANAGES RISK**, **ENHANCES VALUE** FOR ALL, AND **STEWARDS NATURAL RESOURCES**

SUSTAINABLE STORMWATER TASK FORCE GUIDING PRINCIPLES

The sustainable stormwater task force identified the following guiding principles:

Risk Management

- Build systems that adapt to ever-changing climate impacts and function beyond our lifetimes.
- Enhance both the community and natural systems.
- Employ inclusive, interdisciplinary, and interagency planning processes to ensure that water infrastructure serves communities.
- Address downstream impacts from the intertwined elements of water quality, volume, and peak flow rates for the full range of rainfall events.

Value

- Promote that stormwater infrastructure is valuable and of equal importance to communities as other public infrastructure.
- Recognize rainfall is a resource to provide more equitable stormwater systems. • Connect community and natural systems by blending overland flow, pipe, and green infrastructure systems.
- Design, build, maintain, and evaluate systems that protect and enhance long-term triple bottom line benefits.
- Protect and enhance public health benefits through connected open spaces.

Stewardship

- Promote activities that create a net-positive watershed-wide contribution.
- Restore the health of receiving waterbodies and the natural environment
- Educate our communities and decision makers about the human connection to water, including through storytelling.
- Incorporate restorative soil and vegetative management practices to maximize infiltration and habitat vitality.

TASK FORCE TIMELINE

- **August 31, 2020**: Task force results provided to the KC Metro Chapter of APWA Executive Committee.
- **May 21, 2021**: Task force recommendations were published in the KC Metro Chapter of APWA March 2021 newsletter.
- **October 20, 2021**: Executive Committee approved the task force recommendations.
- **November 17, 2021**: Executive Committee approved a plan to update the regional stormwater design standards and engaged MARC to secure funding and to develop request for proposals (RFP).
- **February 17, 2023**: RFP for updating the regional stormwater management standards released.

Stormwater resiliency aims to create systems that can withstand and adapt to extreme storm events, minimizing environmental, social, and economic impacts. As part of the update process, stakeholders identified key drivers to revise the existing stormwater criteria. Addressing these key drivers tie to the vision for resilient watersheds across the region. These key drivers included:

1. Reduce Overall Flood Risk
2. Improve Water Quality
3. Reduce Stream Erosion
4. Provide More Affordable Solutions
5. Improve Stormwater Infrastructure Performance
6. Incentivize Sustainable Development/Redevelopment
7. Improve Communities
8. Reduce green infrastructure maintenance costs
9. Protect and enhance natural system
10. Create more resilient improvements

APWA 5600 AND MARC BMP MANUAL UPDATE

MARC, in collaboration with the KC Metro Chapter of APWA and local municipalities, administered the selection of a consultant team to update the regional stormwater design criteria which included APWA Section 5600 and the Mid-America Regional Council Manual of Best Management Practices (MARC BMP Manual). On April 6, 2023, the consultant team of Burns & McDonnell, Black & Veatch, Vireo, and Center for Watershed Protection was selected. The consultant team was managed by MARC and 32 municipalities that served as the management stakeholders (Table 5600-1). From July 2023 through March 2025 the consultant team and management stakeholders held monthly meetings to first develop the process for the stormwater criteria updates, second to engage stakeholders through a series of meetings and workshops, and finally to develop the draft and final design manual. The engagement process was inclusive of more than 240 different stakeholders and extensive engagement including more than 50 meetings and workshops resulting in over 1,400 stakeholder-hours.

Table 5600-1: Management Stakeholders

Blue Springs, MO	Lawrence, KS	Overland Park, KS
Bonner Springs, KS	Leawood, KS	Parkville, MO
De Soto, KS	Lenexa, KS	Prairie Village, KS
Excelsior Springs, MO	Liberty, MO	Riverside, MO
Fairway, KS	Merriam, KS	Roeland Park, KS
Gardner, KS	Miami County, KS	Shawnee, KS
Gladstone, MO	Mission Hills, KS	Spring Hill, KS
Grandview, MO	Mission, KS	Unified Government of Wyandotte County, MO
Independence, MO	North Kansas City, MO	Westwood Hills, KS
Johnson County, KS	Olathe, KS	Westwood, KS
Kansas City, MO	Osawatomie, KS	

This updated manual represents the culmination of thousands of hours of effort and input from the region's stormwater leaders to achieve the first set of comprehensive design criteria that addresses both stormwater runoff quantity and quality. The level of effort to accomplish this should not be understated; the infrastructure outcomes resulting from using this manual are a monumental step forward for the region in providing more resilient and adaptive stormwater designs.

Watersheds across the region span multiple cities and counties which require that similar stormwater management criteria be consistent across the watershed. In order to be successful in implementing the desired watershed approach, most or all of the criteria in this manual must be adopted across the MARC region. **Regional adoption would provide holistic and more resilient stormwater design criteria that reduce flooding, improve water quality, and steward our natural resources**. Uniform adoption and implementation of this manual is imperative to achieve the vision of the Sustainable Stormwater Task Force and other stakeholders.

This design criteria manual marks a monumental step forward towards the desired outcomes of more sustainable, cost-effective, and adaptive stormwater designs that provide more functional value in mitigating downstream risks, improving water quality, and creating multiple-benefit, lower maintenance solutions. This manual provides the requirements, the design details, evaluation tools, and submittal requirements that can achieve these outcomes. It is important to understand that improved stormwater management can only be achieved through the diligent implementation of consistent requirements over a long period of time to achieve greater stormwater infrastructure performance for improved watershed benefits.

The KC Metro Chapter of APWA, MARC, and the consultant team want to express a sincere thank you to all that were involved in this effort.

Sincerely,

Mid-America Regional Council

KC Metropolitan Chapter of the American Public Works Association

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5601

INTRODUCTION

5601 INTRODUCTION

The KC Metro Chapter of the American Public Works Association (APWA) in cooperation with the Mid-America Regional Council (MARC) and over 30 communities are responsible for this updated stormwater design criteria manual that integrates stormwater quantity and quality. This manual combines and supersedes the previous version of APWA Section 5600 Storm Drainage Systems & Facilities (February 16, 2011) and the MARC Manual of Best Management Practices for Stormwater Quality (October 2012), herein referred to as APWA 5600 and the MARC BMP Manual, respectively. Stormwater quantity and quality management systems are inherently connected and functionally dependent on one another. This combined manual brings forward the integration of natural and engineered systems to enhance ecosystem services in managing water resources while increasing stormwater resiliency.

5601.1 BACKGROUND

This manual update was based on recommendations from the Sustainable Stormwater Task Force (KC Metro Chapter of APWA 2019). The purpose of the task force was to advance the discussion of the state of the stormwater community of practice in our region, to develop ideas for improving our regional stormwater standards, and to provide recommendations to the KC Metro Chapter of APWA. The task force developed a vision statement along with guiding principles for improved stormwater management. This vision and guiding principles support more resilient and sustainable communities that set the foundation for the updated design criteria developed herein. Additional background information and details on the manual development process are presented in the **Preamble** to this manual

5601.2 REGIONAL STANDARDS

The purpose of a regional stormwater standard is to define uniform criteria to improve stormwater management across watersheds and to create more resilient communities. The MARC region represents a nine-county area which includes 92 cities. The KC Metro Chapter of APWA stretches over a similar area including Platte, Clay, Jackson, Cass, and Ray counties in Missouri, and Johnson, Leavenworth, Wyandotte, and Miami counties in Kansas. This manual generally applies throughout the MARC Region as well as surrounding communities, with location-specific adjustments for rainfall inputs.

The MARC Region includes the Kansas City Metro area and surrounding communities including 9 counties and 92 cities.

Figure 5601-1: Mid-America Regional Council 9-County Region

MARC. (2022). A Stronger Kansas City Region. https://www.marc.org/

5601.3 APPLICABILITY

Disclaimer: **Use of this criteria on a project does not alleviate the need for professional judgement and technical review confirming that the proposed improvements do not cause harm to individuals, property, and/or to the environment. It is the responsibility of the designer, contractor, and/or owner to evaluate, review, and approve the overall stormwater improvements based on the requirements provided herein.**

This design criteria manual should be applied to all site development and to public infrastructure improvement projects that are outside the authority of Federal Emergency Management Agency (FEMA), United States Army Corps of Engineers (USACE), United States Department of Transportation (DOT), or other regulatory authorities with stormwater design criteria. This criteria is not meant to replace or supersede FEMA floodplain criteria, USACE civil works project criteria, DOT requirements, state or federal dam requirements, levees and/or other high-hazard infrastructure. It is the responsibility of each municipal jurisdiction to determine the specific applicability of these design criteria.

5601.4 INTRODUCTION TO PROJECT TYPES

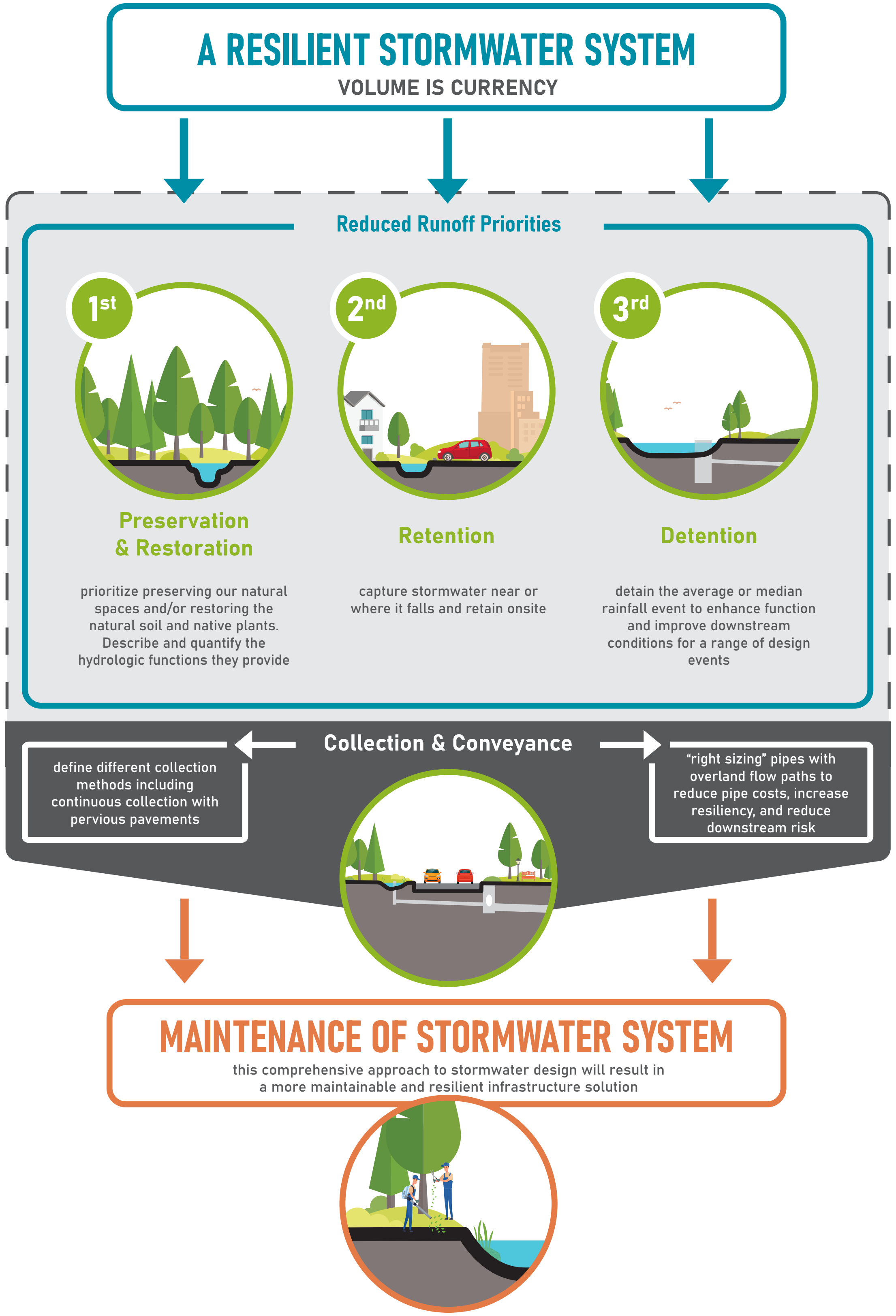
Project types define equitable stormwater management requirements such that improvements contribute to the overall management of stormwater within the watershed in a feasible and implementable manner. Some project types may be exempt from portions of this criteria. Requirements are also impacted by whether the project is **new development** or **redevelopment**. Project types are defined as the following:

Site Development 	Project type representing improvements done to a parcel or parcels of land including both public and private development projects such as residential, subdivisions, commercial, industrial, multi-use, solar farms, and non-linear municipal or utility facilities. For the purpose of this criteria, **site development** includes the roadways completed as part of the larger **common plan of development**.
Public Roadway Improvements 	Project type representing public right-of-way improvements to the street or associated public infrastructure including but not limited to curb and gutter, ditches, curb ramps, sidewalks, and bike lanes. If any modifications to the stormwater infrastructure are required for the improvements, this criteria shall apply. For the purpose of this criteria, **public roadway improvement** projects do not include resurfacing within an existing pavement section, roadways developed as part of a larger common plan of development (see site development project type), linear trail improvements, or emergency repairs.
Utility Improvements 	**Utility improvements** are exempt from meeting retention and detention requirements, but when impacting the storm sewer system shall meet requirements for collection and conveyance.

5601.5 PRIORITIES OF STORMWATER MANAGEMENT

This manual defines priorities for stormwater management in order of importance to achieve the desired resilient watershed outcomes. Designers are required to consider the following practices to achieve comprehensive stormwater management for their projects. It is recommended that the priorities are considered in the following order of priority:

Figure 5601-2: Priorities of Stormwater Management



- **1st – Preserve or Restore:** Preserve existing natural areas, existing trees and native plants where possible. Set back from streams and reserves to protect natural riparian areas. Where preservation is not possible, restore previously impacted areas to more natural conditions by improving soils, planting native plants, and adding back trees. Preserved natural areas and/or restored areas reduce runoff through plant/tree canopy interception of rainfall, surface storage in micro pools within dense vegetation, higher infiltration rates into more porous topsoil, and delayed runoff through rougher ground surface. Combining all of these hydrologic benefits results in reduced runoff volume, slower runoff rates, and more green spaces. **Preservation** or **restoration** of **natural areas** absorb a significant amount of runoff for the most frequent rain events. During larger rainfall events these areas provide the additional benefits of capturing and slowing down the rate of rainfall runoff, reducing this energy impact on downstream systems. Identifying opportunities for preservation and restoration within a project will significantly reduce the stormwater management requirements.
- **2nd – Retain On-Site:** Provide on-site **retention** for frequent rainfall events using **green stormwater infrastructure** (GSI) practices. This method, known as a **runoff reduction method**, quantifies runoff volume as the stormwater management and water quality currency and has been applied across the country as a best practice to meet stormwater regulations, improve downstream water quality, increase the available capacity of downstream stormwater systems, support green spaces, sustain plants, replenish groundwater, and reduce potable water uses with onsite stormwater re-use opportunities. The volume of rainfall retained on-site replaces the previous value rating system formerly used to evaluate stormwater best management practices (BMPs). The retention volume requirements must be met to meet **water quality** regulations.
- **3rd – Detain On-Site: Detention** of stormwater is necessary to offset the hydrologic impacts caused by adding more impervious surface, improving the efficiency of stormwater collection and conveyance, and/or the loss of surface storage. Detention is vital to reduce downstream flood risks, improve the sustainability of existing enclosed systems, and to reduce stream erosion. Retention volume is credited towards the detention volume, which reduces the physical size of the required storage onsite. Therefore, the retention and detention volumes are to be managed together to improve the overall function of detention, reduce maintenance, and increase the overall resiliency of the stormwater system.

In addition to the stormwater priorities, the following are necessary components and considerations for design of a holistic **storm drainage system**:

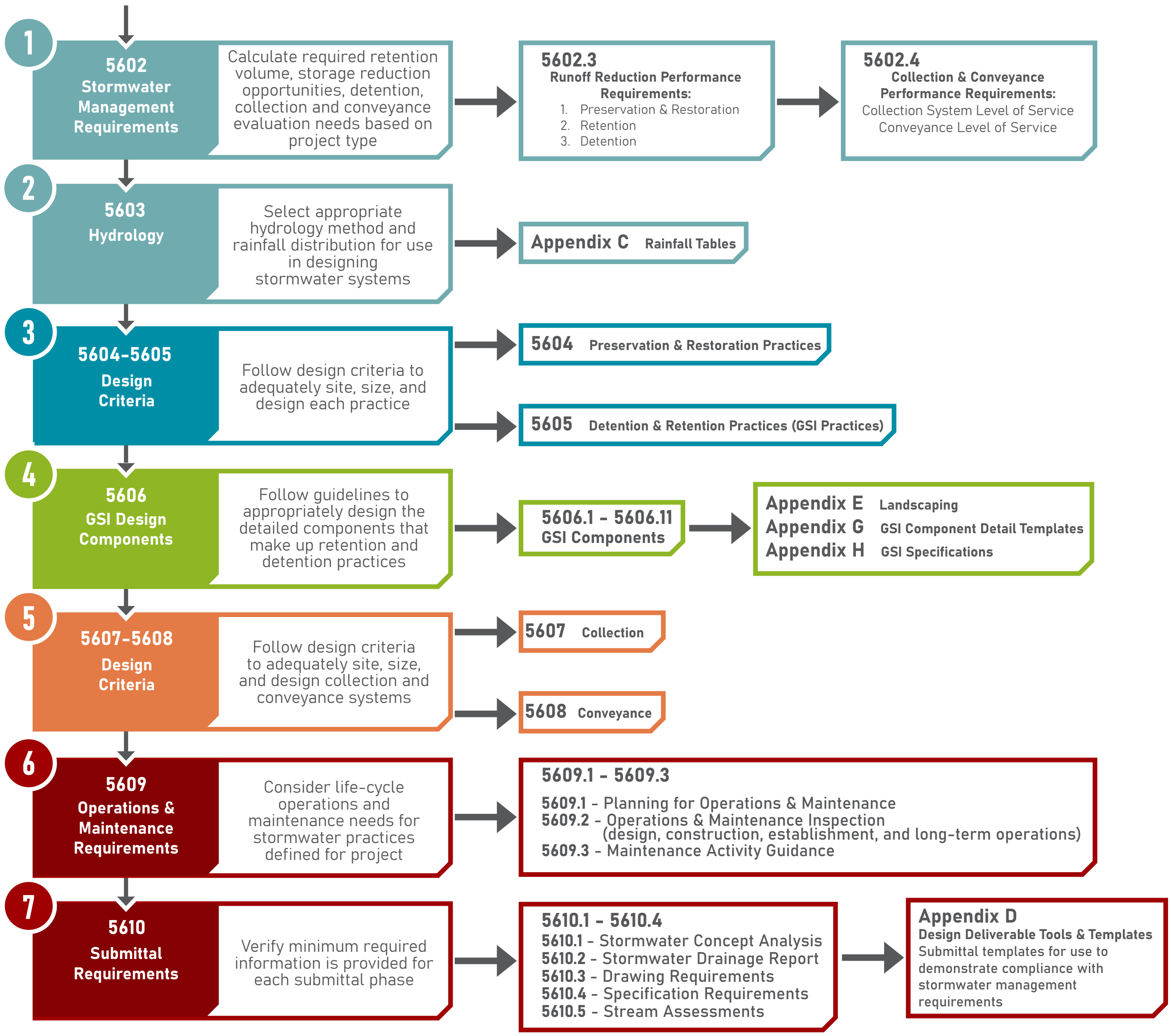
- **Collection and Conveyance**: Stormwater **collection practices** and **conveyance practices** are critical components of stormwater management. Location and sizing of collection and conveyance components should consider a range of flow rates, from small storms to potentially larger rainfall events. Resilient conveyance systems consider all paths that rainfall runoff can take through this range of storms, including **enclosed pipe systems** and **open channel systems**, while understanding **overland drainage paths**. Providing a **designated overflow route** for larger rainfall events adds resiliency to the system.
- **Maintenance:** Stormwater infrastructure should be planned and designed with maintenance in mind to create a sustainable infrastructure solutions. Without proper maintenance of both gray and green infrastructure the functionality of a stormwater system degrades, increasing risk and reducing the performance and design life of the asset. Stormwater infrastructure requires a proactive maintenance plan, including formal designations of responsibility such as who owns each asset, who is responsible for maintenance, and who is responsible for inspection.

5601.6 HOW TO USE THE MANUAL

Beyond the **Preamble** and this Introduction section, the manual is structured to walk the user through the process of designing the stormwater management system for their project. This starts with understanding the stormwater management requirements the project is expected to meet based on the project type and site parameters. Accompanying this manual is the **KC Compliance Calculator** tool, to create a standardized format for calculations that can be used by both designers and reviewers. Next, the manual defines the appropriate and acceptable hydrology methods and inputs needed to complete the required design calculations. It then moves into the detailed criteria to design and construct the applicable preservation and restoration, retention, detention, collection, and conveyance practices and components for the **storm drainage system**. Maintenance planning and requirements for each of the stormwater management components are then outlined for the various stages of the asset's life. Lastly, submittal requirements are summarized to demonstrate that the design criteria have been met, to confirm design documents include the necessary details to construct the stormwater systems, and to define the long-term maintenance responsibility. Figure 5601-3 provides a graphic depiction of the key sections and how the user is intended to move through the manual as design progresses.

> Throughout the manual, key terms that are defined in **Appendix A** are identified with **bold blue** text the first time they appear in a section or subsection.

Figure 5601-3: How to Use this Manual



5602

STORMWATER MANAGEMENT REQUIREMENTS

5602 STORMWATER MANAGEMENT REQUIREMENTS

This section defines the stormwater management requirements and calculation procedures for all applicable project types. Procedures and equations are provided to calculate site requirements for stormwater management practices. The goal of site requirements are to reduce rainfall runoff from a project site through preservation and/or restoration, retention, detention, as well as define performance requirements for the collection and conveyance components of a **storm drainage system**. These requirements should be considered and integrated in the beginning stages of project planning. The **KC Compliance Calculator** is a tool accompanying this manual that includes the equations defined herein. Criteria to complete detailed design for preservation and/or restoration practices (5604), retention and detention practices (5605) and components (5606), collection (5607), and conveyance (5608) can be found in subsequent sections.

5602.1 APPLICABILITY

This design criterion shall apply to all **new development** and **redevelopment**, including both public and private site development, public roadway improvements, and utility improvements that disturb the surface of the land.

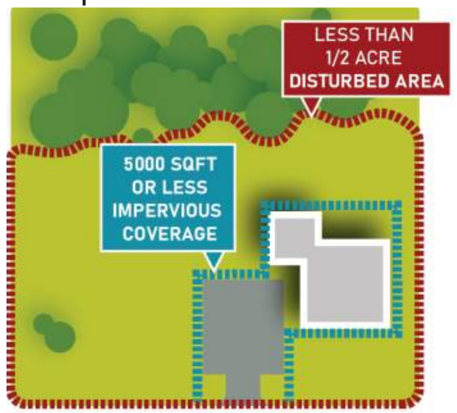
The following exceptions apply:

1. Improvements that have less than ½ acre of **disturbed area** and have less than 5,000 square feet of total **impervious area**.
2. Single-family or duplex developments that are not part of a larger **common plan of development** with a lot size less than 1 acre or **impervious coverage** less than 35% of the total lot area.
3. Construction of any site having previously provided stormwater management as part of a larger common plan of development assuming fully developed conditions, previously approved by the **approving jurisdiction** prior to adoption of this stormwater criteria.

Larger-scale projects such as watershed studies and floodplain analyses expand beyond the scope of this criteria.

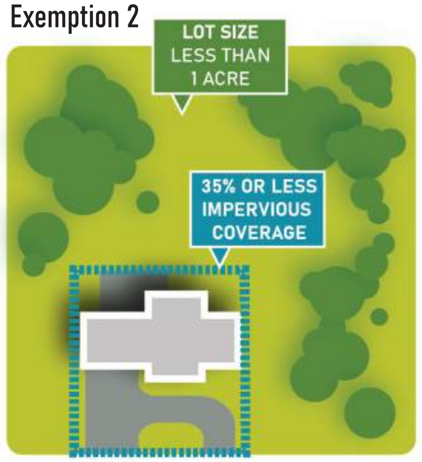
Throughout the manual, key terms that are defined in Appendix A are identified with **bold blue** text the first time they appear in a section or subsection.

Exemption 1



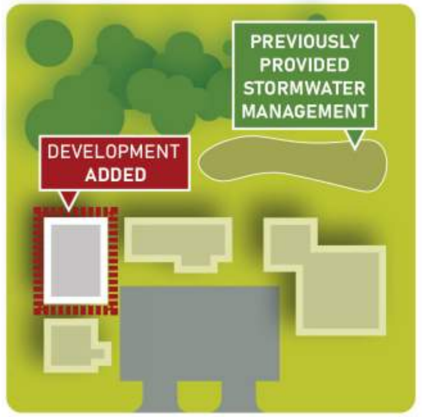
General Site Developments
[Fulfills **both** of the requirements]

Exemption 2



Single Family / Duplex Developments Not Part of a Larger Common Plan of Development
[Fulfills **one or more** of the requirements]

Exemption 3



Site Development within a Larger Plan with Existing Stormwater Management
[Stormwater previously accounted for within the larger development assuming fully developed conditions]

Figure 5602-1: Applicability Flowchart - General

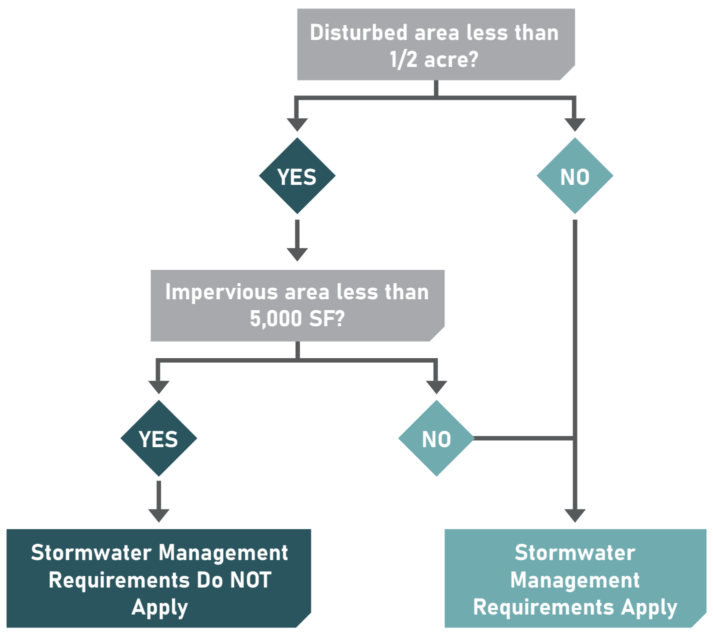
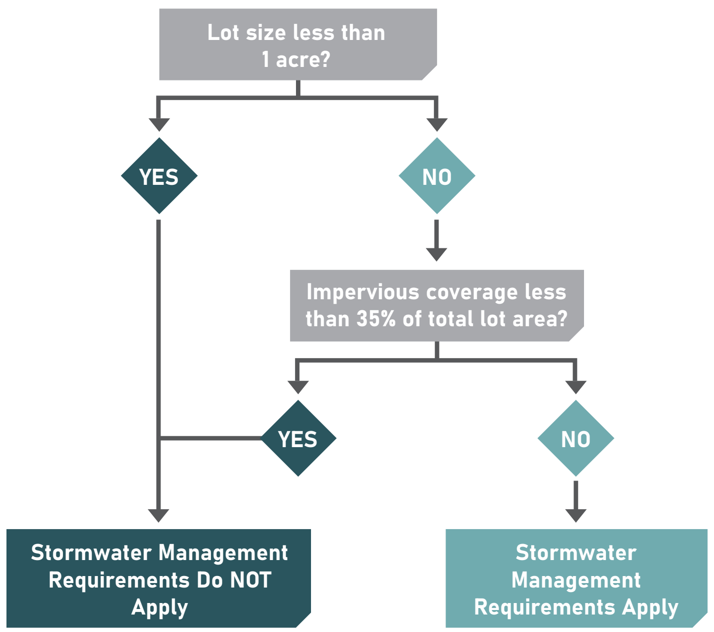


Figure 5602-2: Applicability Flowchart - Single Family or Duplex Development



5602.2 PROJECT TYPES

Stormwater management requirements vary by project type. Some project types may be exempt entirely from portions of this criteria. Requirements are also impacted by whether the project is **new development** or **redevelopment**, as defined in Appendix A. For the purpose of this manual, project types are defined as:

Site Development	Project type representing improvements done to a parcel or parcels of land including both public and private development projects such as residential, subdivisions, commercial, industrial, multi-use, solar farms, and non-linear municipal or utility facilities. For the purpose of this criteria, **site development** includes the roadways completed as part of the larger common plan of development.
Public Roadway Improvements	Project type representing public right-of-way improvements to the street or associated public infrastructure including but not limited to curb and gutter, ditches, curb ramps, sidewalks, and bike lanes. If any modifications to the stormwater infrastructure are required for the improvements, this criteria shall apply. For the purpose of this criteria, **public roadway improvement** projects do not include resurfacing within an existing pavement section, roadways developed as part of a larger common plan of development (see site development project type), linear trail improvements, or emergency repairs.
Utility Improvements	Project type representing linear utility construction including but not limited to electric, gas, communications, water, sanitary, or storm sewer improvements. **Utility improvements** are exempt from meeting retention and detention requirements, but when impacting the storm sewer system shall meet requirements for collection and conveyance.

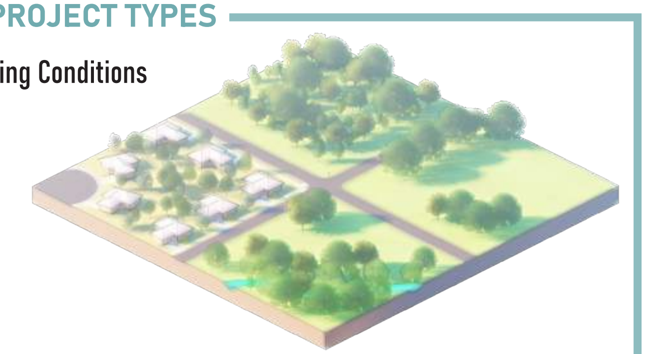
5602.3 RUNOFF REDUCTION PERFORMANCE REQUIREMENTS

Runoff reduction methods shall be implemented to address the stormwater volume, quality, and peak flow rate impacts caused by changes to the land surface. Runoff reduction performance requires use of stormwater management practices to meet a **required reduction volume** (RRV) and maximum allowable **release rates**. This section defines the baseline runoff reduction performance requirements for preservation and/or restoration, retention, and detention for each project type. This is achieved through the following approach:

1. **Preservation & Restoration**: Identify opportunities for preservation or restoration of **natural areas** within a dedicated tract of land restricted from future development. Prioritization of preservation and/or restoration practices recognizes the stormwater management and ecological benefit of natural areas. For the purpose of this criteria, it is assumed that natural areas meeting the requirements of Section 5604 produce no runoff for small events up to and including the **water quality storm** event, and, if these areas also receive stormwater runoff from other parts of a site, may reduce the RRV for the project, as specified in Section 5602.3 A.
2. **Retention**: Calculate the RRV based on the proposed condition's impervious, pervious, and natural area cover types. Identify **required retention volume reduction** ($RRV_{reduction}$) reduction opportunities specified in Section 5602.3 B. Locate retention practices to provide storage for the RRV for the water quality storm event.
3. **Detention**: Calculate required detention release rates to manage peak flows based on the existing and proposed project conditions. Calculate the **retention-adjusted curve number** (CN_R) for each required **design event** based on the storage volume provided by retention practices (V_R). Locate and size detention practices to provide the necessary storage of stormwater runoff to meet the allowable release rates for required design events.

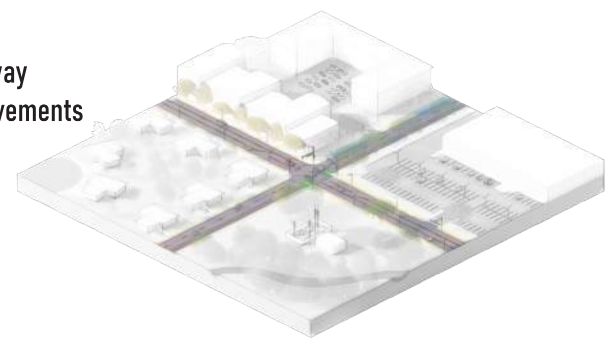
PROJECT TYPES

Existing Conditions

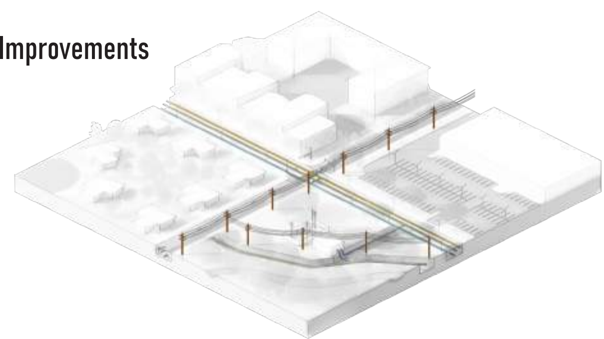


Site Development

Public Roadway Improvements



Utility Improvements

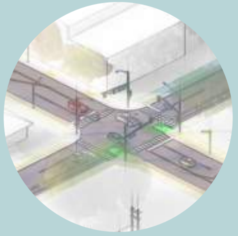
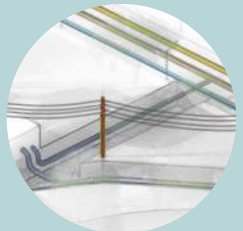


A. Preservation & Restoration

With the exception of **stream setbacks,** preservation and/or restoration of natural areas is not required as a part of a project; however, incorporating preservation and/or restoration will reduce a project's RRV and detention requirements. Stream setback preservation requirements are described in Section 5604.

Table 5602-1 summarizes the preservation and/or restoration performance requirements, with additional descriptions and methods for design calculations provided in the following subsections. For detailed criteria for designing preservation and/or restoration practices, see Section 5604.

Table 5602-1: Preservation & Restoration Performance Requirements & Incentives

Project Type	New Development	Redevelopment	Preservation & Restoration Incentives
Site Development 	Maintain required stream setbacks defined in Table 5604-2 and per Section 5608.	→ For work on existing facilities already located within the required stream setback, the disturbed area shall not increase the encroachment to the stream setback unless authorized by the approving jurisdiction.	Reduce RRV through: → Preservation and/or restoration of natural areas → RRV reductions (sheetflow to natural area, sheetflow to pervious area, downspout disconnection, tree preservation, and new trees)
Public Roadway Improvements 	→ Maintain required stream setbacks defined in Table 5604-2 and per Section 5608. → Restore unpaved areas within impacted stream setbacks per Section 5604.3.		Reduce RRV through: → Preservation and/or restoration of natural areas → RRV reductions (sheetflow to natural area, sheetflow to pervious area, downspout disconnection, tree preservation, and new trees)
Utility Improvements 	→ Maintain required stream setbacks defined in Table 5604-2 and Section 5608. → Restore areas within impacted stream setbacks per Section 5604.3.		Not Applicable.

Stream Setbacks

Stream setbacks qualify as natural areas for RRV calculations. Stream setbacks where the stream has a tributary area more than 20 acres shall be preserved. For work on existing facilities already located within the stream setback, the disturbed area shall not increase the encroachment to the stream setback unless authorized by the approving jurisdiction.

Preservation of streams with a tributary area between 20 and 40 acres may be waived by the approving jurisdiction where it results in the property being substantially undevelopable for the landowner provided that all of the following requirements are met:

- ➔ The landowner provides at least a functional equivalency of the existing system in the same drainage area that includes the same setback minimums
- ➔ The replacement system is clearly in the public interest
- ➔ The project has received appropriate state and federal permits.

Preservation of streams with tributary areas less than 20 acres and associated stream setback is encouraged. Preserving setbacks on smaller streams or providing additional setback widths will result in reductions to the project's RRV as defined in the following subsections.

Stream setbacks must be placed in a separate dedicated tract of land restricted from future development with the intent for the stream riparian vegetation to be maintained into perpetuity. Minimum stream setbacks by drainage area are defined in **Table 5604-2.**

Preserved & Restored Natural Areas

Identify opportunities for preservation or restoration of natural areas. Preserved or restored natural areas meeting the requirements of **Section 5604** can assume no runoff when placed within a dedicated tract of land restricted from future development. The following key benefits can be recognized with implementation of natural area tracts on a project:

- ➔ Maximizing natural areas reduces RRV.
- ➔ RRV reductions can be achieved when the natural area is receiving stormwater runoff from the project site.
- ➔ Placing open channel conveyance practices meeting the restoration requirements of **Section 5604** in dedicated restored natural areas can reduce RRV. This could simultaneously meet requirements for routing larger storms as defined in 5602.4 B.

RRV Reductions

The RRV may be reduced by incorporating any of the following RRV reduction practices:

a. **Sheetflow to Natural Areas**: Natural Areas may be used for stormwater management when receiving non-concentrated flow, or concentrated flow that is discharged through a level spreader per **Section 5606, GSI-2.4.**

- ➔ Sheetflow to natural areas provides retention for 100% of the stormwater runoff volume that is draining to it, provided that all of the following criteria are met:
  - » The natural area meets all of the requirements of **Section 5604.2 A**.
  - » Energy dissipation and pretreatment are provided prior to stormwater discharge to the natural area per **Section 5606, GSI-2**.
  - » *The natural area footprint must be 2 times or greater in size than the developed area discharging to it per Equation 5602-1:*

Equation 5602-1:

$$A_{\text{Natural Area}} > 0.5 * (I_{\text{Tributary Area}} + P_{\text{Tributary Area}})$$

$A_{\text{Natural Area}}$ = Footprint of natural area that is receiving non-concentrated stormwater runoff via sheetflow or level spreader (ft^2)

$I_{\text{Tributary Area}}$ = Developed impervious area tributary to the Natural Area (ft^2)

$P_{\text{Tributary Area}}$ = Developed pervious area tributary to the Natural Area (ft^2)

  - » *The maximum flow path from the tributary drainage area must be equal to or less than the flow path through the natural area and the natural area flow path slope must be less than 5%.*
  - » The RRV reduction ($RRV_{reduction}$) for sheetflow to natural areas is calculated per Equation 5602-2:

Equation 5602-2:

$$RRV_{\text{Reduction}} = \frac{P_{WQ}}{12} * [0.95 I_{\text{Tributary Area}}]$$

$RRV_{\text{Reduction}}$ = Reduction to Required Retention Volume based on sustainable site practice implemented (ft^3)

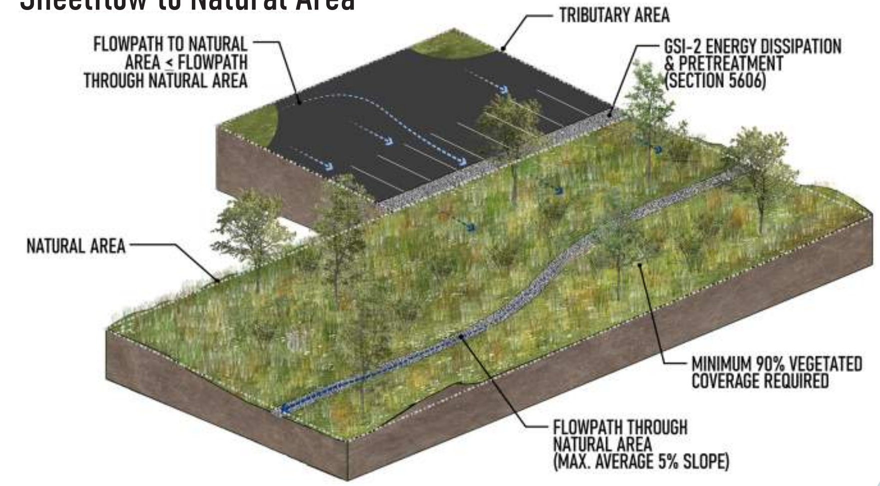
P_{WQ} = Rainfall for Water Quality Storm Event (in), 1.37 for the Kansas City Metropolitan Area

12 = Feet to inches conversion

0.95 = Runoff coefficient for impervious area

$I_{\text{Tributary Area}}$ = Impervious area tributary to the Natural Area (ft^2)

Sheetflow to Natural Area



b. **Sheetflow to Pervious Areas**: Vegetated pervious open space areas may be used for stormwater management when receiving non-concentrated flow, or concentrated flow that is discharged through a level spreader per **Section 5606, GSI-2.4**.

➔ Sheetflow to pervious area provides retention for 50% of the stormwater runoff volume produced from the tributary impervious area that is draining to it, provided that the following criteria are met:

» *The adjoining pervious area footprint must be equal to or greater in size than the impervious area discharging to it:*

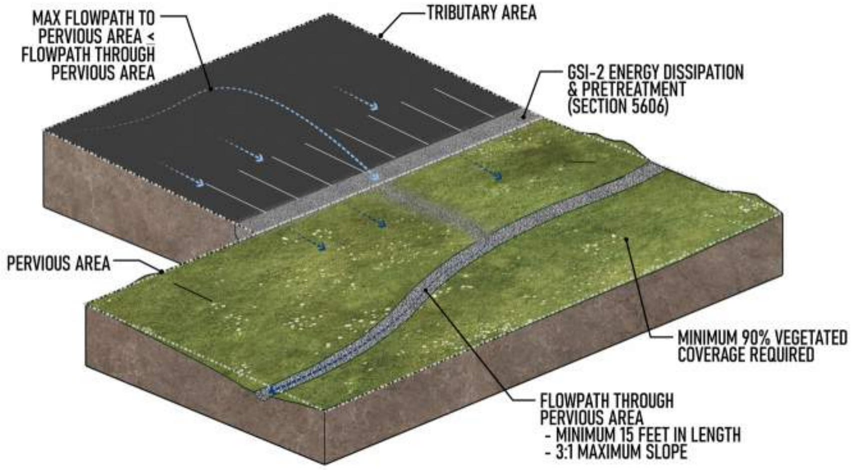
Equation 5602-3:

$$A_{Pervious\ Area} > I_{Tributary\ Area}$$

$A_{Pervious\ Area}$ = Footprint of pervious area that is receiving non-concentrated stormwater runoff via sheetflow or level spreader (ft^2)

$I_{Tributary\ Area}$ = Impervious area tributary to the pervious area (ft^2)

Sheetflow to Pervious Area



» The maximum flow path from the tributary drainage area must be equal to or less than the flow path through the pervious area

» The flow path through the pervious area must be a minimum of 15 feet and have an average slope 3:1 (H:V) or shallower.

» The pervious area must be vegetated and achieve a minimum of 90% coverage.

➔ The RRV reduction ($RRV_{reduction}$) for sheetflow to pervious areas is calculated as follows:

Equation 5602-4:

$$RRV_{Reduction} = \frac{P_{WQ}}{12} * 0.50 * [0.95 I_{Tributary\ Area}]$$

$RRV_{Reduction}$ = Reduction to Required Retention Volume based on sustainable site practice implemented (ft^3)

P_{WQ} = Rainfall for Water Quality Storm Event (in), 1.37 for the Kansas City Metropolitan Area

12 = Feet to inches conversion

0.50 = Sheetflow to pervious area retention volume reduction percentage. Value is 50% for sheetflow to pervious areas

0.95 = Runoff coefficient for impervious area

$I_{Tributary\ Area}$ = Impervious area tributary to the Natural Area (ft^2)

c. **Downspout Disconnection**: For non-residential development only, vegetated pervious open space areas may be used for stormwater management for runoff from roof drainage systems directed there rather than to an impervious surface or an enclosed conveyance system.

➔ Downspout disconnection provides retention for 25% of the stormwater runoff volume produced from the tributary roof area that is discharged to it, provided that all of the following criteria are met:

» The pervious area footprint must be equal to or greater in size than the roof area discharging to it:

Equation 5602-5:

$$A_{Pervious\ Area} > I_{Roof\ Area}$$

$A_{Pervious\ Area}$ = Footprint of pervious area that is receiving stormwater directly from a roof drainage system (ft^2)

$I_{Roof\ Area}$ = Roof area discharging to the pervious area through a roof drainage system (ft^2)

» The flow path through the pervious area must be a minimum of 15 feet and have an average slope less than 2.5%.

» Energy dissipation measures must be incorporated at the outlet of the roof drainage system per **Section 5606, GSI-2**.

» The pervious area must be fully vegetated and achieve a minimum of 90% coverage.

➔ The RRV reduction ($RRV_{reduction}$) for downspout disconnection is calculated as follows:

Equation 5602-6:

$$RRV_{Reduction} = \frac{P_{WQ}}{12} * 0.25 * [0.95 I_{Roof\ Area}]$$

$RRV_{Reduction}$ = Reduction to Required Retention Volume based on sustainable site practice implemented (ft^3)

P_{WQ} = Rainfall for Water Quality Storm Event (in), 1.37 for the Kansas City Metropolitan Area

12 = Feet to inches conversion

0.25 = Downspout disconnection retention volume reduction percentage. Value is 25% for downspout disconnection

0.95 = Runoff coefficient for impervious area

$I_{Roof\ Area}$ = Impervious area tributary to the Natural Area (ft^2)

d. **Preserve Existing Trees**: Preserving existing trees within the disturbed area of the site and outside of preserved natural areas provides stormwater management benefits through interception of rainfall, improved infiltration and evapotranspiration. To qualify for this credit all trees must meet the requirements of **Section 5604**.

➔ Provided that the trees meet the criteria defined in **Section 5604.2 B**, existing trees provide retention of 20 ft^3 per preserved tree. The RRV reduction ($RRV_{reduction}$) for existing trees is calculated as follows:

Equation 5602-7:

$$RRV_{Reduction} = 20 * T_{Preserved\ Trees}$$

$RRV_{Reduction}$ = Reduction to Required Retention Volume based on sustainable site practice implemented (ft^3)

20 = Runoff reduction volume per tree (ft^3)

$T_{Preserved\ Trees}$ = Total number of preserved trees within disturbed area of the project

e. **Plant New Trees**: Planting new trees within the disturbed area of the site provides stormwater management benefits through interception of rainfall, improved infiltration and evapotranspiration. To qualify for this credit all trees must meet the requirements of **Section 5604**.

➔ Provided that the new trees meet the criteria defined in **Section 5604.3 B**, new trees provide retention of 10 ft^3 per tree installed. The RRV reduction (RRVreduction) for new trees is calculated as follows:

Equation 5602-8:

$$RRV_{Reduction} = 10 * T_{New\ Trees}$$

$RRV_{Reduction}$ = Reduction to Required Retention Volume based on sustainable site practice implemented (ft^3)

10 = Runoff reduction volume per tree (ft^3)

$T_{New\ Trees}$ = Total number of new trees within disturbed area of the project

B. Retention

Stormwater retention shall be required to manage runoff produced from the disturbed area for the Water Quality Event Storm. The RRV shall be managed using practices meeting the requirements of **Section 5605**. Retention volume requirements may be achieved independently or within a detention practice provided the retention volume is provided below the **primary outlet structure**.

Table 5602-2 summarizes the stormwater retention performance requirements, with additional descriptions and methods for design calculations provided in the following subsections. For detailed criteria for designing retention practices or their design components, see **Sections 5605** and **5606**, respectively.

Table 5602-2: Stormwater Retention Performance Requirements

Project Type	New Development	Redevelopment	Combined Sewer System Area*
Site Development	Retention of 85% of RRV	Retention of 40% of RRV	Retention of 100% of RRV for new development & 85% for redevelopment
Public Roadway Improvements	Retention of 40% of RRV ➔ See **Section 5605.3** for application of typical roadway retention practice sections for a simplified approach to meeting requirements.	Retention of 20% of RRV ➔ See **Section 5605.3** for application of typical roadway retention practice sections for a simplified approach to meeting requirements.	Retention of 100% of RRV for new roadway improvements and 65% for redeveloped public roadways
Utility Improvements	Exempt	Exempt	Exempt

* Combined sewer area that are under a federal consent decree to reduce combined sewer overflows. Requirements of the federal consent decree may be more stringent than what is provided herein. Designer shall confirm with approving jurisdiction combined sewer system requirements.

Required retention volume (RRV) is calculated as follows:

Equation 5602-9:

$$RRV = \frac{P_{WQ}}{12}\left[0.00N + 0.95I + 0.25P + Rv_X X\right] * PT\ \%$$

RRV = Required Retention Volume (ft³)

P_{WQ} = Rainfall for Water Quality Storm Event (in), per **Section 5603.2, A**.

12 = Feet to inches conversion

0.00 = Runoff coefficient for preserved or restored natural area

N = Natural area of preservation or restoration within the project site within a dedicated tract of land restricted from future development (ft²). Note:

- ➔ Preserved natural areas not receiving stormwater runoff from the project can be excluded from the disturbed area extents altogether.
- ➔ Preserved natural areas within the project area receiving stormwater runoff must be included in the disturbed area extents.
- ➔ Restored natural areas within the project area must be included in the disturbed area extents.

0.95 = Runoff coefficient for impervious area

I = Impervious area within the disturbed area (ft²)

0.25 = Runoff coefficient for pervious area

P = Pervious area within the disturbed area, not including any Natural Areas (ft²)

Rv_X = Runoff coefficient for other unique land cover types:

Table 5602-3: Runoff Coefficients for Unique Land Cover Types

Other Land Cover (X)	RvX
Solar Panels (native inter-panel ground surface)	0.40
Solar Panels (gravel inter-panel ground surface)	0.60
Gravel (overflow parking lots, trails/maintenance paths, or substations)	0.60
Gravel (primary parking lots, access driveways, railroad ballasts)	0.80
Gravel (public roads with compacted subsurface material)	0.95
Artificial Turf (applications with subsurface drainage system)	0.45
Artificial Turf (applications without subsurface drainage system)	0.80
Water Surfaces	1.0

X = Are of other type within the disturbed area (ft²)

PT% = Project Type Percentage of RRV required to be controlled by each project type defined in Table 5602-4 and Table 5602-5

Table 5602-4: Project Type and Project Type Percentage (PT%)

Project Type[1]	Project Type Percentage (PT%)	
	New Development	Redevelopment
Site Development	85%	40%
Public Roadway Improvements	40%	20%
Utility Improvements	0%	0%

[1]Project Types are defined in **Appendix A.** PT% represent minimum values to meet stormwater management requirements.

Table 5602-5: Combined Sewer Area Project Type and PT%

Project Type[1]	Project Type Percentage (PT%)	
	New Development	Redevelopment
Site Development	100%	85%
Public Roadway Improvements	100%	65%
Utility Improvements	0%	0%

[1]Project Types are defined in **Appendix A.** PT% represent minimum values to meet stormwater management requirements.

C. Detention

Detention is required to offset the increase in runoff rates from changes to the land that impact how stormwater is managed. The required **release rates** are set to control the release for the smaller, more frequent storm events through the **primary control structure** while allowing larger, less frequent events to safely pass through the facility through the **secondary control structure** and **overflow spillway**, without overtopping the basin. Peak runoff control shall be provided for a range of design storms to provide broad protection of the receiving system and downstream communities, including channel erosion protection and peak flood reductions. No exemption of detention based on assumed peak timing justifications shall be allowed without a full-scale watershed model to justify the assumptions and demonstrate the detention would result in an adverse impact for all design events. Design storms for detention shall be based on the NOAA **Temporal Rainfall Distributions** as defined in **Section 5603**.

Table 5602-6 summarizes the stormwater detention performance requirements, with additional descriptions and methods for design calculations provided in the following subsections. For detailed criteria for designing detention practices, see **Section 5605**.

Table 5602-6: Stormwater Detention Performance Requirements

Project Type	New Development	Redevelopment
Site Development	Peak outflow control for the maximum allowable release rates per Table 5602-7 shall be provided for the following design events: ➔ 2-year ➔ 10-year ➔ 100-year	Peak outflow control for the maxiumum allowable release rates per Table 5602-7 shall be provided for the following design events: ➔ 2-year ➔ 10-year
Public Roadway Improvements	Discharge to the existing storm drainage system shall not exceed existing discharge rates assuming an existing condition CN=69 for the following design events: ➔ 2-year ➔ 10-year	Discharge to the existing storm drainage system shall not exceed one of the following: ➔ Release rate < 1.6 cfs/acre OR ➔ 2-year and 10-year release rate < existing conditions assuming capacity and efficiency of existing system matches field conditions, including inlet and pipe clogging and time of concentration
Utility Improvements	Exempt	Exempt

Allowable Release Rates

Post-project peak discharge rates shall not exceed the allowable releases expressed in discharge per tributary area defined in Table 5602-7. Detention release rates should be calculated based on the **Retention Adjusted Curve Number (CN_R)** defined in the following subsection.

Table 5602-7: Detention Maximum Allowable Release Rates

Design Storm	Required Release Rate (cfs/acre)	Allowable Release Source
2-Year	0.20	**Primary control structure**
10-Year	0.60	**Secondary control structure**
100-Year	3.00	Secondary control structure + **overflow spillway**
Reference **Section 5605.2** for minimum orifice or opening size requirements.		

Retention Adjusted Curve Number

Retention practices used to meet the RRV will reduce the required detention volume for the project by increasing the initial abstraction recognized in the upstream tributary area. Retention adjusted Curve Numbers (CN_R) shall be used to calculate peak flows from proposed detention practices. CN_R can be calculated as follows:

1. Based on proposed site conditions, calculate initial abstraction and total runoff volume for each design storm using the NRCS Curve Number Method.

Equation #1:

$$S = \frac{1000}{CN} - 10$$

Equation #2:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

S = Potential abstraction (inches)

CN = Post project curve number, prior to factoring in retention as defined in **Section 5603**. If multiple land covers are defined within the tributary area to the detention, use the area-weighted CN.

Q = Total runoff volume for design storm precipitation depth, P (inches)

P = Design storm precipitation depth (inches)

2. Convert the total volume provided by the proposed retention practices from cubic feet to inches.

$$V_{R,\,in} = \frac{V_R}{A_{disturbed}} * 12$$

$V_{R,\,in}$ = Total storage volume provided by proposed retention practices (inches)

V_R = Total storage volume provided by proposed retention practices (ft^3)

$A_{Disturbed}$ = Total disturbed area of the site (ft^2)

12 = Feet to inches conversion

3. Solve the modified runoff volume equation for the retention-adjusted potential abstraction based on the storage volume provided by upstream retention practices.

$$Q - V_{R,\,in} = \frac{(P - 0.2S_R)^2}{(P + 0.8S_R)}$$

S_R = Retention-adjusted initial abstraction based on the retention volume provided by upstream retention practices

Q = Total runoff volume for design storm precipitation depth, P (inches)

$V_{R,\,in}$ = Total storage volume provided by proposed retention practices (inches)

P = Design storm precipitation depth (inches)

4. Calculate a new, retention-adjusted curve number based on the retention-adjusted initial abstraction.

$$CN_R = \frac{1000}{S_R + 10}$$

CN_R = Retention-adjusted curve number based on storage volume provided by upstream retention practices

S_R = Retention-adjusted initial abstraction based on the retention volume provided by upstream retention practices

5. Use the CN_R to calculate peak flow rates for each design storm using a dynamic model. Note that the value for CN_R will vary depending on the design storm depth, as the impact of the volume stored by retention practices is greater for small storm events than it is for larger storm events. If multiple landcovers and CN are defined within the tributary area to the detention basin, all tribuatary area CN values may be revised to CN_R for detention basin sizing only.

D. Runoff Reduction Performance Calculations

Runoff reduction performance calculations for the project shall be documented in the **KC Compliance Calculator**. Calculating the runoff reduction requirements for the site includes the following steps, with detailed equations defined in the previous subsections:

1. Select the project type percentage based on the project type and the type of receiving sewer system to which the project is tributary as defined in Table 5602-4 or Table 5602-5.
2. Define the project's overall disturbed area identifying natural areas for preservation or restoration within the project site, noting the following distinctions:
   a. Preserved natural areas not receiving stormwater runoff from the project can be excluded from the disturbed area extents.
   b. Preserved natural areas within the project area receiving stormwater runoff must be included in the disturbed area extents.
   c. Restored natural areas within the project area must be included in the disturbed area extents.
3. Define post-project drainage areas including **uncontrolled drainage area**.
   a. Identify the overland drainage paths for the project based on post-project topography and identify each project site **discharge point**. Delineate proposed condition drainage areas to each discharge point for the project's disturbed area.
   b. The uncontrolled drainage area represents the portion of a project's disturbed area from which it is impractical to capture and convey stormwater runoff to a retention or detention practice. The percentage of uncontrolled drainage area to total disturbed area cannot exceed the **project type percentage**.
4. Define post-project land cover, CN, and runoff coefficient R_v for both controlled and uncontrolled drainage areas within the site's disturbed area.
   - ➔ Post-project **Curve Number (CN)** values are defined in **Section 5603** by cover type and soil type.
   - ➔ Runoff coefficient R_v values are defined in Table 5602-3.
5. Calculate the RRV for each drainage area, including uncontrolled drainage area, and the total RRV for the project.
6. Calculate a new project type percentage to be used for the controlled area ($PT\%_{controlled}$) factoring in the RRV for the uncontrolled drainage area to be used for the individual drainage area RRV calculations.

$$PT\%_{controlled} = \frac{(RRV * 12)}{P_{WQ} * (A_{controlled} * R_{v,\,controlled})}$$

$PT\%_{controlled}$ = Project Type Percentage of RRV required to be controlled by each project type defined in Table 5602-2, modified to account for uncontrolled area on the project site.

RRV = Required Retention Volume (ft^3)

12 = Feet to inches conversion

P_{WQ} = Rainfall for Water Quality Storm Event (in), per **Section 5603.2, A**.

$A_{controlled}$ = Total drainage area being controlled by stormwater management practices (ft^2)

$Rv_{controlled}$ = Area-weighted runoff coefficient for controlled drainage area

$$Rv_{controlled} = \frac{\sum A_1 * Rv_1 + A_2 * Rv_2 + A_3 * Rv_3 \ldots}{A_{controlled}}$$

A_1 = Controlled drainage area (ft^2)
Rv_1 = Runoff coefficient for controlled drainage area 1

7. Define retention practices for each drainage area, as follows:

   a. Calculate the RRV for the drainage area using the new $PT\%_{controlled}$

   b. Identify RRV reductions

      ➔ Calculate the total RRV reductions ($RRV_{reduction}$) in each drainage area. The total RRV reduction volume is equal to the sum of each qualifying $RRV_{reduction}$

$$RRV_{reduction} = \sum RRV_{reductions} = RRV_{reduction,\ a} + RRV_{reduction,\ b} + RRV_{reduction,\ c} + RRV_{reduction,\ d} + RRV_{reduction,\ e}$$

$RRV_{reduction}$ = Reductions to RRV (ft^3) per **Section 5602.3, A**
a. Sheetflow to Natural Areas
b. Sheetflow to Pervious Areas
c. Downspout Disconnection
d. Tree Preservation
e. New Tree Installation

   c. Calculate the new required retention volume for each drainage area ($RRV_{DA\ \#}$) by subtracting the $RRV_{reduction}$ from the RRV.

$$RRV_{DA\#} = RRV - RRV_{reduction}$$

$RRV_{DA\#}$ = Required retention volume for drainage area ID (DA #), where # should align with drainage area designations for the project (ft^3)
RRV = Required retention volume for DA # prior to applying $RRV_{reduction}$ (ft^3)
$RRV_{redctions}$ = Total reduction to required retention volume (ft^3)

   d. Locate and size retention practices per **Section 5605** such that the storage volume provided by retention practices (V_R) meets or exceeds the $RRV_{DA\ \#}$.

8. Define detention practices for each drainage area, as follows:

   a. Calculate retention adjusted curve number (CN_R) based on V_R provided.

   b. Locate and size detention per **Section 5605** using a dynamic model to meet maximum allowable release rates defined in Table 5602-7 using the CN_R for the entire area tributary to the detention basin.

9. Repeat process for each controlled drainage areas .

10. Confirm retention storage provided meets or exceeds the RRV for each individual drainage area as well as cumulatively for the total project. ($V_R \geq RRV$)

5602.4 COLLECTION & CONVEYANCE PERFORMANCE REQUIREMENTS

Collection and **conveyance** components of the **storm drainage system** define how stormwater is captured from the ground surface and safely routed to the downstream receiving system. The NOAA **Nested Rainfall Distributions** defined in **Section 5603** shall be used for design of all collection and conveyance features.

A. Collection

Stormwater collection requirements are defined for vehicular areas to maintain safe travel ways. Collection can be achieved through the use of traditional inlet structures, **retention** practices, or a combination of both. Table 5602-8 summarizes the stormwater collection performance requirements. For detailed criteria for designing **collection practices** of a storm drainage system, see **Section 5607**.

Table 5602-8: Stormwater Collection Performance Requirements

	Traditional Inlet Placement Requirements	Retention Practice Integration
Parking Lots	➔ Collection required in sump locations	➔ Utilize retention practices per **Section 5605** for collection within medians, islands, and along perimeter to meet both collection needs and RRV
Roads < 45 MPH	➔ Collection required at sump locations and **driver decision points** where roaway users must react ➔ Collection points spaced at minimum intervals based on roadway longitudinal slope per Table 5607-1 through Table 5607-4 to limit gutter spread	➔ Utilize retention practices per **Section 5605** to meet RRV or convey to regionalized retention practice for the project ➔ For public redevelopment projects, standardized roadway retention practices may be placed upstream of each traditional inlet at maximum spacing per Table 5607-5 (**Section 5607**)
Roads ≥ 45 MPH	➔ Collection locations defined by gutter spread per **Section 5607.2 B**	➔ Retention practices should follow respective Department of Transportation (DOT) requirements

B. Conveyance

A stormwater conveyance system shall be required when the drainage area is 2 acres or more and such that property not reserved or designed for conveying stormwater shall be protected from frequent inundation. The stormwater conveyance system requirements may be met with one or a combination of the following conveyance practices:

➔ Enclosed Pipe System

➔ Open Channel (overland drainage path, overflow routing, natural streams, or engineered channels)

➔ Curb and gutter streets

Each conveyance system component shall be designed to meet a required stormwater level of service and shall also include a **designated overflow route** to manage flows in excess of the engineered conveyance system design capacity.

Table 5602-9 summarizes the stormwater conveyance performance. For detailed criteria for hydraulic calculations and design for conveyance components of a storm drainage system, see Section 5608.

Table 5602-9: Stormwater Conveyance Performance Requirements

	Conveyance Component	Design Level of service Requirements	Overflow Routing Requirements
	Minor Drainage Systems (<2-acre tributary area)	When the total drainage area is less than 2 acres, implement lot-to-lot overland drainage practices defined in **Section 5608.4.**	A designated overflow route for runoff generated by the 100-year design storm shall be provided meeting the following requirements: ➔ Minimum of 2-feet freeboard at all building openings above the 100-year design storm at any point along the drainage system, in accordance with the current edition of the International Building Code or as required by the City/County ➔ Flood-proofing of building below the 100-year design storm plus minimum 2-feet of freeboard, in accordance with the current edition of the International Building Code or as required by the City/County ➔ Non-habitable accessory buildings are sometimes provided less protection by local City/County ordinances or policies. Consult local authority for exceptions. Property not reserved or designed for conveying stormwater shall also be protected from frequent inundation (2-year design event or less).
	Enclosed Pipe System	➔ Convey 10-year design storm with surcharging at least 0.5 feet below the lowest opening to the surface or structure rim elevation, whichever is lower. ➔ Energy dissipation at outfalls shall be designed to withstand discharge from the enclosed system during the 10-year design event	
	Open Channel Systems	➔ Convey 10-year design storm within banks of channel ➔ Energy dissipation at outfalls shall be designed to withstand discharge from the enclosed system during the 10-year design event	
	Channel Crossings	➔ **Channel crossings** will be designed to completely convey design flows without street overtopping in accordance with **Section 5608.4** C. » <45 MPH = 10-Year » ≥45 MPH = 50-Year ➔ No adverse impacts upstream and downstream (**Section 5608**) of the crossing structure for the following design events: » 2-year » 5-year » 10-year » 25-year » 50-year » 100-year	

5602.5 EXAMPLE APPLICATIONS & RENDERINGS

No two sites are alike. During development and redevelopment, the designer should consider how stormwater flows into and through the existing site, what facilities are desired on the proposed site, what stormwater requirements the site must meet, what GSI Practices can be used to meet those stormwater requirements, and where those GSI Practices should be located on the site. The following pages depict how green stormwater infrastructure can be incorporated in the following development and redevelopment scenarios:

- ➔ Parking Lot
- ➔ Parking Garage
- ➔ Commercial Infill (Redevelopment)
- ➔ Residential Neighborhood (New Development)
- ➔ Streetscape

These renderings are included to invoke creativity when thinking about stormwater management and GSI in site development. The renderings provide examples of GSI Practices in different redevelopment scenarios and are not intended to be patterns or templates.

Parking Lot

Pages 30-31 illustrate how GSI could be incorporated into a parking lot serving a mixed use commercial development. The site includes a mid-rise residential building with ground level retail, professional offices, and a small hotel served by central surface parking. The example is a redevelopment of a former light industrial site but could just as easily represent new commercial, retail, office or hotel construction. GSI captures and treats runoff from rooftops and surface parking using a variety of GSI Practices that also integrate into the landscape design to create attractive features that add value to the site. Specific strategies include:

Parking Lot Strategies. The example parking lot employs several green infrastructure practices to manage its on-site stormwater and promote infiltration adjacent to impervious surfaces. In portions of the parking lot, water is captured by inlets with integrated pretreatment devices, which are components that collect trash and sediment while allowing water to pass through a screen and into a GSI Practice. The pretreatment devices are located next to the pavement where they can be easily serviced by maintenance crews. The screened runoff then flows into bioretention, which are depressed parking lot islands with native plants that help absorb stormwater and infiltrate it into the ground that also serve as landscape features. Growing media soaks up water and supports the plants, while overflow outlets, underdrains and outlet control structures safely convey excess flow from large rainfalls into the piping system and off site. In the other half of the parking lot, the roundabout and parking bays use permeable pavement that allow the runoff to soak directly beneath the pavement into storage aggregate media, and eventually into the soil below. In the example, interlocking red brick pavers create a traditional look while allowing water to pass through the joints.

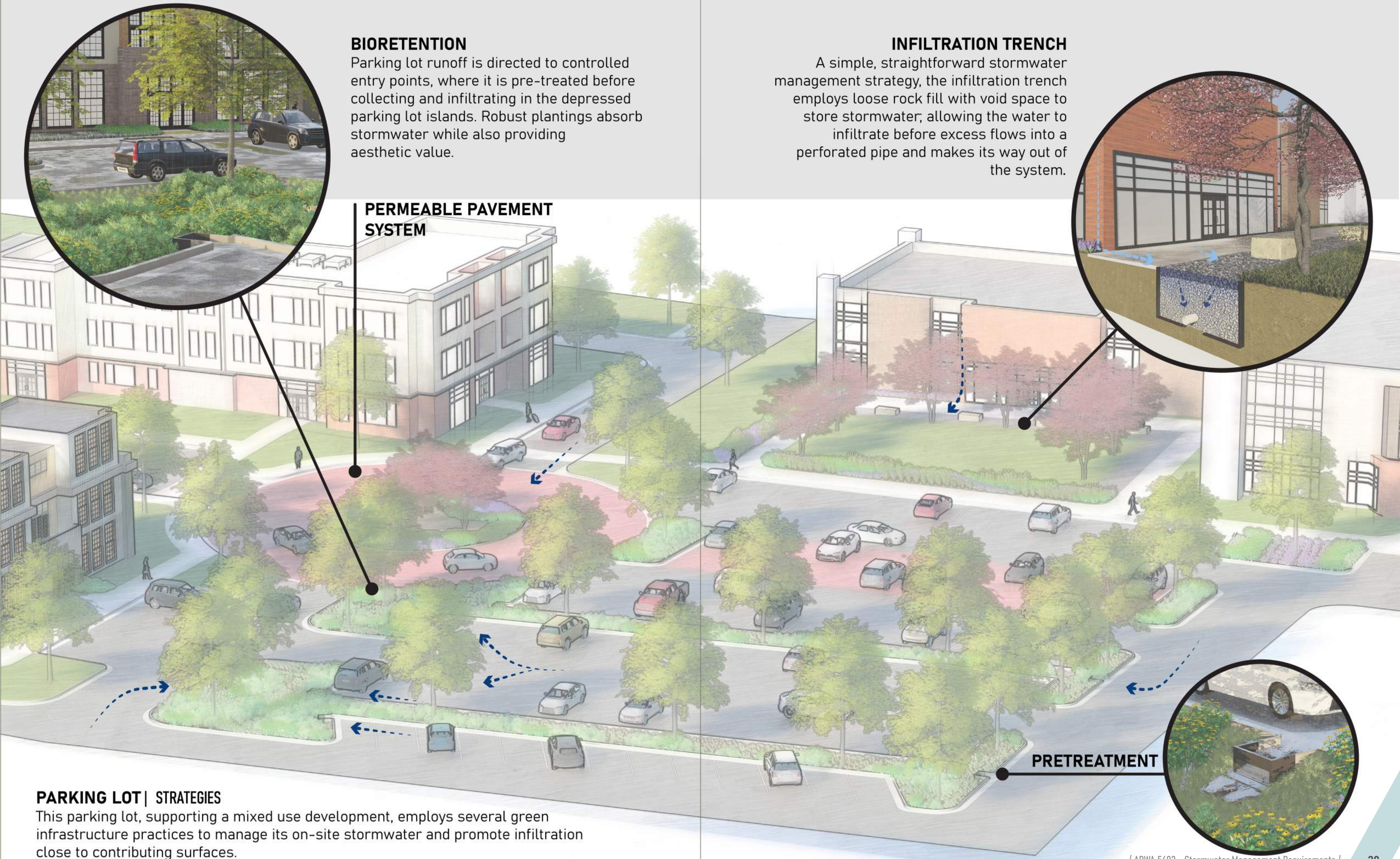
Building Strategies. Rooftop and sidewalk runoff are directed away from building foundations and into infiltration trenches positioned on the outside edge of walkways. Care should be taken to direct runoff away from buildings so not to impact foundations. Roof leaders may empty onto grassy areas that drain into the trenches or may be piped beneath walkways and other paved surfaces and directly into the storage aggregate media. The trenches are architecturally defined and topped with clean decorative gravel on the surface, allowing water to soak into the ground while also watering the roots of adjacent trees. An underdrain carries excess water to the storm sewer, keeping the decorative gravel surface dry. Limestone blocks atop the gravel create a shady sitting area for visitors and employees. Evaporation from the trench and evapotranspiration from the trees cools the area, and the trees shade the building exterior and reduce energy costs.

BIORETENTION

Parking lot runoff is directed to controlled entry points, where it is pre-treated before collecting and infiltrating in the depressed parking lot islands. Robust plantings absorb stormwater while also providing aesthetic value.

INFILTRATION TRENCH

A simple, straightforward stormwater management strategy, the infiltration trench employs loose rock fill with void space to store stormwater; allowing the water to infiltrate before excess flows into a perforated pipe and makes its way out of the system.



PARKING LOT | STRATEGIES

This parking lot, supporting a mixed use development, employs several green infrastructure practices to manage its on-site stormwater and promote infiltration close to contributing surfaces.

Parking Garage

Pages 32 – 33 demonstrate how GSI could be incorporated into a parking garage serving an office and industrial complex. This urban redevelopment scenario includes a distribution center, storage for heavy construction materials, and a multistory office building for line workers and administrative staff. The parking garage serves several users, including personal vehicles and fleet vehicles on different levels.

Parking Garage Strategies. Space is at a premium in urban areas, and for this reason mainly below-grade structures are used in this example to collect, treat, store, and infiltrate stormwater runoff from the parking structure and surrounding paved surfaces. One exception is roof leaders that drain to cisterns at the building corners, which capture rainwater to water the landscaping around the garage perimeter. Additional runoff flows into various types of pretreatment systems that capture trash, floatable objects, and sediment. Baffle boxes in the drive area use successive chambers to direct flow over and beneath weirs to separate out the different materials, which can be removed through manholes. The pretreated water then flows into underground storage chambers to store and infiltrate water into the ground. Open-bottom arched pipes placed over storage aggregate media are used in the drive area, while in tighter spaces such as along the street, more compact box structures may be placed beneath the sidewalk.

Building Strategies. One way to improve the capacity of stormwater infrastructure at the surface and below ground is to capture rainfall on rooftops before it ever hits the ground. The distribution center is topped by a green roof with vegetation that utilizes the water. An "extensive" green roof system consists of a thin layer of growing media that supports shallow-rooted vegetation and a drainage layer underneath that holds excess water until it can be absorbed. The system includes a waterproof membrane to protect the roof itself, and integrated drainage pipes to distribute water and direct overflows to the roof leaders. The soil layer helps insulate the building in the winter and the plants help cool it in the summer. Cooling occurs because plants' natural green color reflects infrared radiation from sunlight and evapotranspiration and draws heat away from the roof. The system also protects the membrane and roof from the elements, extending its service life.

Commercial Infill

Pages 34 – 35 show a commercial infill development and an example of what's possible on a compact site, where GSI manages rainfall from the rooftop to the root zone. A multistory building with office space over ground-level retail and surface parking is infused with GSI Practices that provide maximum effectiveness and value.

Building Strategies. The first drops of water to fall are met with a vegetated green roof that soaks up a portion of the water. Extensive green roofs are less than 6 inches deep to limit structural loading on the building, and can be built-in-place or use modular trays filled with a growing media and shallow-rooted vegetation . An "intensive" system, on the other hand, can include up to 18 inches that can sustain a variety of plants. In either case, the soil layer insulates the building in the winter and the plants cool it in the summer by reflecting infrared radiation and through evapotranspiration that draws heat away from the roof. The system also protects the membrane and roof from the elements, extending its service life. An intensive system would create greater weight loads that must be factored into the design, but also soak up much more rainwater and provide greater insulation and cooling benefit. A rooftop terrace creates a space for employees and visitors to enjoy the rooftop garden and surrounding views and could be used as an event space. Pathways provide access to maintain equipment and the roof when needed.

Lot Strategies. Excess water beyond what the roof can absorb is carried by internal downspouts to the surface where it flows into a native vegetation swale that mimics a dry creek bed, and into an extended dry detention basin that also catches rainfall running off the lawn. The basin temporarily stores runoff from frequent storms and releases it slowly back into the stormwater piping system through an outlet structure. The basin is landscaped with native sedges, rushes and wet meadow grasses selected to create a natural appearance and to reduce maintenance. The vegetation filters pollutants from runoff and protects the slopes from erosion. Clumps of more showy flowering plants dot the edges to provide splashes of color and food for butterflies and other pollinators. A patio and trees provide an outdoor "breakroom" for employees seeking some fresh air.

A rain garden on the opposite side of the site collects, stores, and infiltrates a limited volume of surface stormwater runoff. Rain gardens are sunken landscape beds filled with deep rooted vegetation that uses the rainwater and helps it soak into the ground. While planted with many of the same native perennials as the detention basin, a few more ornamental grasses and flowering pollinator plants spruce up its appearance. An overflow outlet and outlet control structure direct overflows into the offsite stormwater piping network.

Parking Lot Strategies. The small parking lot next to the building collects stormwater as well. The permeable pavement parking row allows the rainfall landing on its surface and runoff from the drive to soak directly through the joints and into storage aggregate media, then into the underlying soil. While pervious concrete and porous asphalt may be used, the example uses simple yet attractive, interlocking pavers. Many colors are available, from traditional red or more vibrant yellow brick, to simpler grays and earth tones.

PARKING GARAGE | STRATEGIES

This parking garage, adjacent to an industrial facility, primarily utilizes below-grade structures to collect, store, and infiltrate stormwater runoff from the parking structure and surrounding paved surfaces.

CISTERN

A roof-catchment rainwater cistern captures stormwater from the parking garage, allowing it to be re-used for non-potable irrigation of on-site landscape areas.

PRETREATMENT

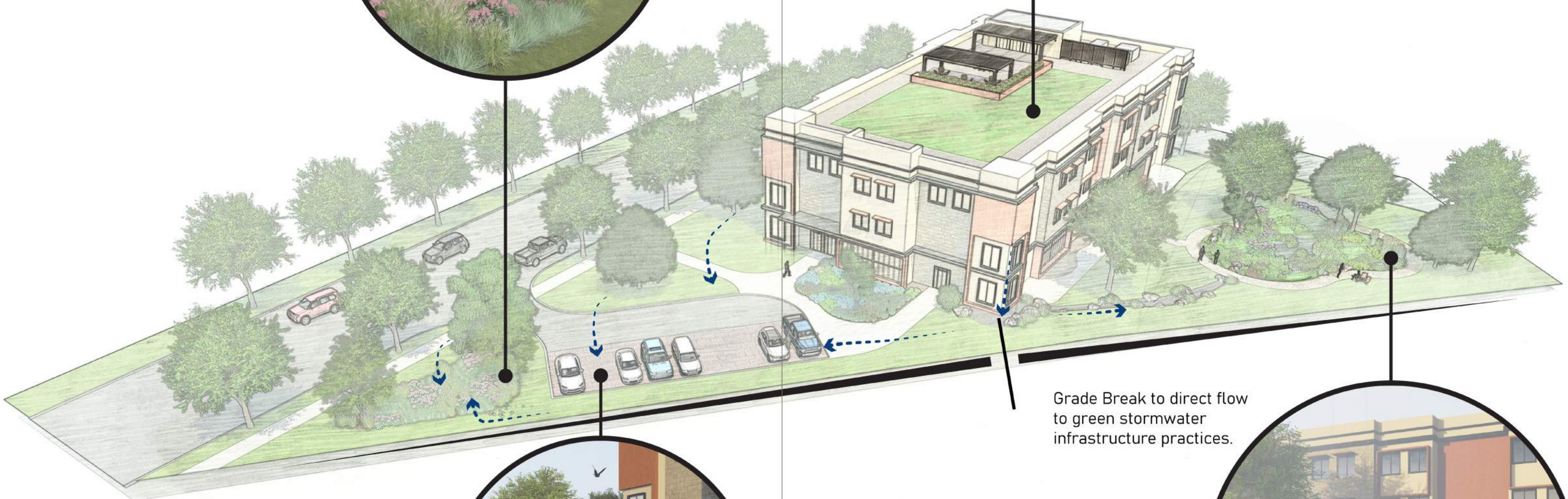
A pretreatment device is an important component of a green infrastructure system, providing capture and storage of sediment, debris, and trash, keeping it separated for easy cleanout. The illustration at right depicts a baffle box. Other examples include vortex separators, manufactured inlets, and catch baskets.

RAIN GARDEN

A rain garden is a simplified, small scale bioretention solution that typically collects, stores, and infiltrates a small volume of surface stormwater runoff. They often include perennials and ornamental grasses that provide aesthetic value and critical habitat.

COMMERCIAL INFILL | STRATEGIES

This commercial infill development - on a challenging site - employs several stormwater management strategies to mitigate runoff and meet required detention volumes.



PERMEABLE PAVEMENT SYSTEM

Permeable pavers - when used in place of traditional impermeable surfaces such as concrete and asphalt - reduce impervious area and promote infiltration, thereby reducing stormwater runoff.

EXTENDED DRY DETENTION BASIN

Provides temporary storage of stormwater during and immediately following precipitation events, reducing stormwater runoff rates. Retention can be integrated into the bottom of detention basins by using growing media and native plantings. Detention basins play a critical role in reducing erosion and flood impacts downstream from a range of rainfall events.

Residential Neighborhood

Pages 38 – 39 is an illustration of a new residential development with neighborhood GSI. Where the road right-of-way provides space to spread out, water is collected in a native vegetation swale with the appearance of a dry creek bed, creating a natural feature along the road and sidewalk. Runoff from houses, common areas, and sidewalks sheet flow across the grass, slowing it down and filtering pollutants before it finds its way into the swale. Road runoff is captured by inlets with integrated pretreatment as seen previously in the mixed-use commercial example and released into the swale. In the remainder of the neighborhood, inlets collect road runoff into traditional stormwater piping.

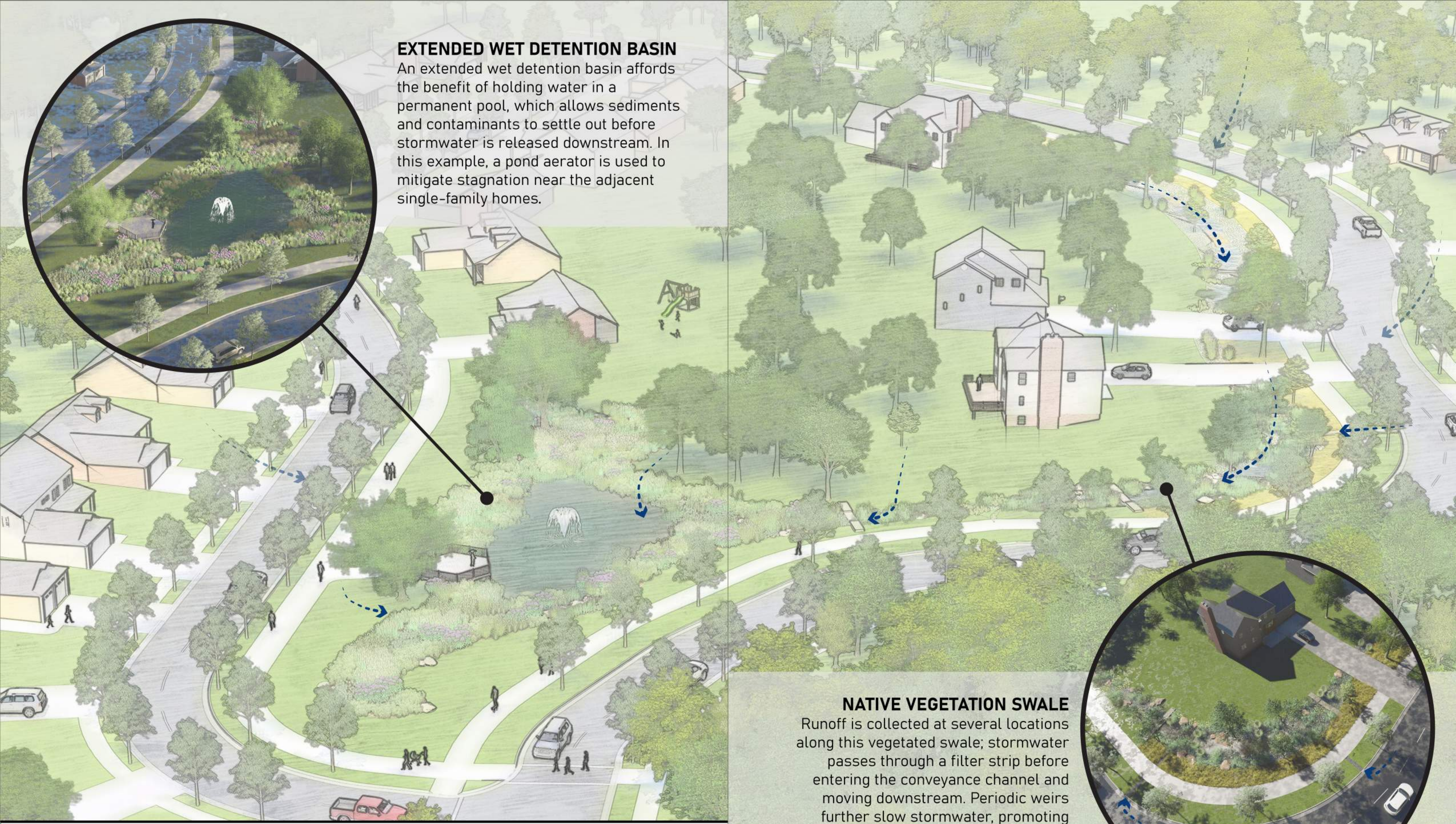
An extended wet detention basin captures, stores and treats the water collected from throughout the neighborhood by the swale and stormwater pipes, and an overflow outlet and outlet control structure releases water back into the storm sewer. This pond is the centerpiece of a beautiful greenspace. The shoreline and shallows are filled with lush emergent native plants that filter runoff, prevent erosion, and create habitat for insects, amphibians and birds. An overlook allows visitors to look out across the pond, and groves of trees create shady spots to relax around the shore. The central fountain creates a focal point while infusing needed oxygen into the water below. A trail creates a walking loop around the greenspace, which residents from throughout the neighborhood can reach using the sidewalk network.

Streetscape

Pages 40-41 highlight a commercial streetscape where GSI is integrated into a multimodal corridor, providing not only stormwater management but also multi-benefit community amenities and enhancing mobility and connectivity. This mixed-use streetscape utilizes two different types of bioretention to capture runoff from the roadway, building roofs, and paved surfaces.

On the left side of the street, premanufactured pretreatment units at the curb inlets provide a single point to capture and filter trash and sediment from street runoff where it can be easily collected and removed. The filtered water flows into a wide swale filled with native vegetation and street trees selected for their ability to survive in unique growing conditions. The plants' deep roots capture and use what rainwater they need while creating pathways to soak additional water into the ground, aided by the growing media. An overflow outlet, underdrain and outlet control structures carry excess water safely away from the buildings and back into the piping system. The vegetation is selected to match the surroundings and create a visual screen between the storefronts and street. The street trees provide shady relief for cyclists and summer patrons, and can contribute to a reduction in building energy use.

On the right side of the street, premanufactured systems of durable plastic cells are filled with growing media and planted with street trees. These compact systems include everything needed to collect and distribute street and sidewalk runoff to support tree health, and can handle the load from pedestrian traffic. The cells are sized to provide enough soil for mature trees, while gently guiding roots and water away from building foundations. The system creates a supportive growing environment to develop full, healthy trees that shade the townhomes and residents and beautify the street corridor.



EXTENDED WET DETENTION BASIN

An extended wet detention basin affords the benefit of holding water in a permanent pool, which allows sediments and contaminants to settle out before stormwater is released downstream. In this example, a pond aerator is used to mitigate stagnation near the adjacent single-family homes.

NATIVE VEGETATION SWALE

Runoff is collected at several locations along this vegetated swale; stormwater passes through a filter strip before entering the conveyance channel and moving downstream. Periodic weirs further slow stormwater, promoting infiltration. Robust, native vegetation tolerates alternating periods of inundation and drought.

RESIDENTIAL NEIGHBORHOOD | STRATEGIES

Stormwater runoff in this suburban neighborhood drains to a shared detention facility, turning an otherwise undevelopable parcel into an amenity for the community, complete with scenic walking trail.

STREETSCAPE | STRATEGIES

This mixed use streetscape utilizes bioretention to capture runoff from the roadway, building roofs, and paved surfaces.

PRETREATMENT

Pre-manufactured pretreatment systems control flow into the bioretention facility and promote easier maintenance by providing a single location for sediment collection and removal.

BIORETENTION

Bioretention comes in many shapes and sizes. This example demonstrates bioretention as a stormwater tree planter that utilizes soil cells to maximize the soil volume of the tree planter, improving tree health and increasing stormwater storage volume.

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5603

HYDROLOGY

5603 HYDROLOGY

This section sets forth the hydrologic parameters and calculations to be used for computations to estimate runoff volumes and flow rates to stormwater **retention** systems, stormwater **detention** systems, and stormwater **collection** and **conveyance** systems.

The term **model** refers to any calculation or set of calculations (including software packages, hand calculations, and spreadsheet tools) which are used for hydrologic analysis and the term **method** refers to the specific equation or set of equations used in the **model**.

Properly representing rainfall-runoff processes is critical to analyzing the hydrologic impacts of **new development** and **redevelopment** projects. The following section discusses the primary components critical for the prediction of hydrologic response.

5603.1 APPLICATION OF HYDROLOGIC CALCULATIONS

The owner is responsible for the management of stormwater runoff generated within these boundaries, as well as stormwater which runs onto the project site from other areas, and shall use the hydrologic methods described in **Section 5603** to complete hydrologic calculations. The following steps shall be executed to apply hydrologic calculations in the design of stormwater infrastructure (these steps need not be executed in the exact order listed below):

A. Drainage Areas Delineation

Delineate areas within the project's **disturbed area** that generate stormwater runoff as well as offsite drainage areas that contribute stormwater run-on to the project site.

1. On a map of appropriate scale, the designer shall clearly delineate the boundaries of proposed development, drainage areas to proposed stormwater controls, and the drainage area boundaries for every point of stormwater run-on from offsite (See **Section 5610** Submittal Requirements for map details).

   ➔ Determine and document the boundaries of the project's disturbed area and delineate drainage areas tributary to proposed stormwater control elements within these boundaries. Stormwater controls which manage stormwater generated on-site will include at least the following elements:

   » **Collection** practices which capture stormwater runoff and direct it to conveyance practices. These practices are described in **Section 5607**.

   Drainage Area

   » **Conveyance** practices which convey captured stormwater to retention facilities, detention facilities, and offsite. These practices are described in **Section 5608**.

   » **Retention** practices which capture runoff generated by the **Water Quality Storm** Event. These practices are described in **Section 5605**.

   » **Detention** practices which manage runoff associated with storms larger than the Water Quality Storm Event. These practices are also described in **Section 5605**.

2. Delineate and document the boundaries offsite drainage areas tributary to the project site at every point of stormwater run-on, regardless of size.

3. Identify and clearly document **discharge points** where concentrated stormwater runoff leaves the project site.

B. Retention Practices

Calculate volume and flows to stormwater retention practices.

1. Select appropriate stormwater retention locations and types, and determine size of practice(s) required using the **Required Reduction Volume (RRV)** formula in **Section 5602.3.B**. This calculation shall be completed for all disturbed areas within the project to determine the total RRV to be managed with retention practices. The RRV shall then be calculated for each retention practice based on the characteristics of the upstream tributary area.

Facilities will not receive credit towards the total site RRV requirement for over-detaining beyond the volume calculated as required by the RRV calculation.

2. Calculate the peak flowrates to GSI capture and conveyance components using the **nested rainfall distribution** described in **Section 5603.2** using the appropriate design storm depth. The following table is a guide which prescribes the hydrologic calculation to be completed to size and design GSI elements.

Table 5603-1: Hydrologic Input to Retention Design Criteria

Retention & Detention Design Component[1]	Required Retention Volume (RRV)	Nested Distribution
GSI-1: Inlets		X
GSI-2: Energy Dissipation & Pretreatment		X
GSI-3: Area Protection	N/A	
GSI-4: Permeable Pavements	X	
GSI-5: Soil & Aggregate Media	X	
GSI-6: Media Liners	N/A	
GSI-7: Landscaping	N/A	
GSI-8: Piping		X
GSI-9: Outlets		X
GSI-10: Storage Chambers	X	
GSI-11: Internal Control, Protection, & Stabilization		X

[1]Retention practices are discussed in Section 5605; Retention design components are discussed in Section 5606.

C. Collection & Conveyance

1. Calculate peak flowrates for each proposed collection and conveyance component to provide required level of service using the nested rainfall distribution described in **Section 5603.2 C**. Apply rainfall depth to the cumulative percent accumulation (**Appendix C**) to develop the rainfall hyetograph for each design storm.

2. Calculate peak flows for stormwater run-on from offsite. The owner is not required to retain or detain offsite stormwater run-on, however, adequate conveyance infrastructure must be provided to maintain required levels of service listed in Table 5608-1. If other studies, such as a FEMA FIS, are available which provide flows at the project site, then these may be used in lieu of site-specific calculations.

D. Detention Practices

1. Calculate flowrates to proposed detention practices using the **temporal distribution** described in **Section 5603.2**. Apply rainfall depth to the cumulative percent accumulation (**Appendix C**) to develop the rainfall hyetograph for each design storm.

2. Identify stormwater outflow points where stormwater leaves the project site. Post-development flowrates at these points are the basis for determining if proposed detention facilities meet outflow performance criteria as described in **Section 5605.1.B**.

5603.2 METEOROLOGY

The rainfall amount and distribution of that rainfall amount over the duration of the storm event is critical in the sizing of stormwater infrastructure. Rainfall depths and distributions for use in design of specific components of the storm drainage system are defined in the following subsections.

A. Rainfall Depth

Water Quality Storm Event

The **water quality storm** (P_{WQ}) is defined as the storm event that produces less than or equal to 90 percent volume of all 24-hour storms on an annual basis. The water quality storm event shall be used for design of all retention practices.

P_{WQ} = Rainfall for Water Quality Storm Event (in), 1.37 for the Kansas City Metropolitan Area

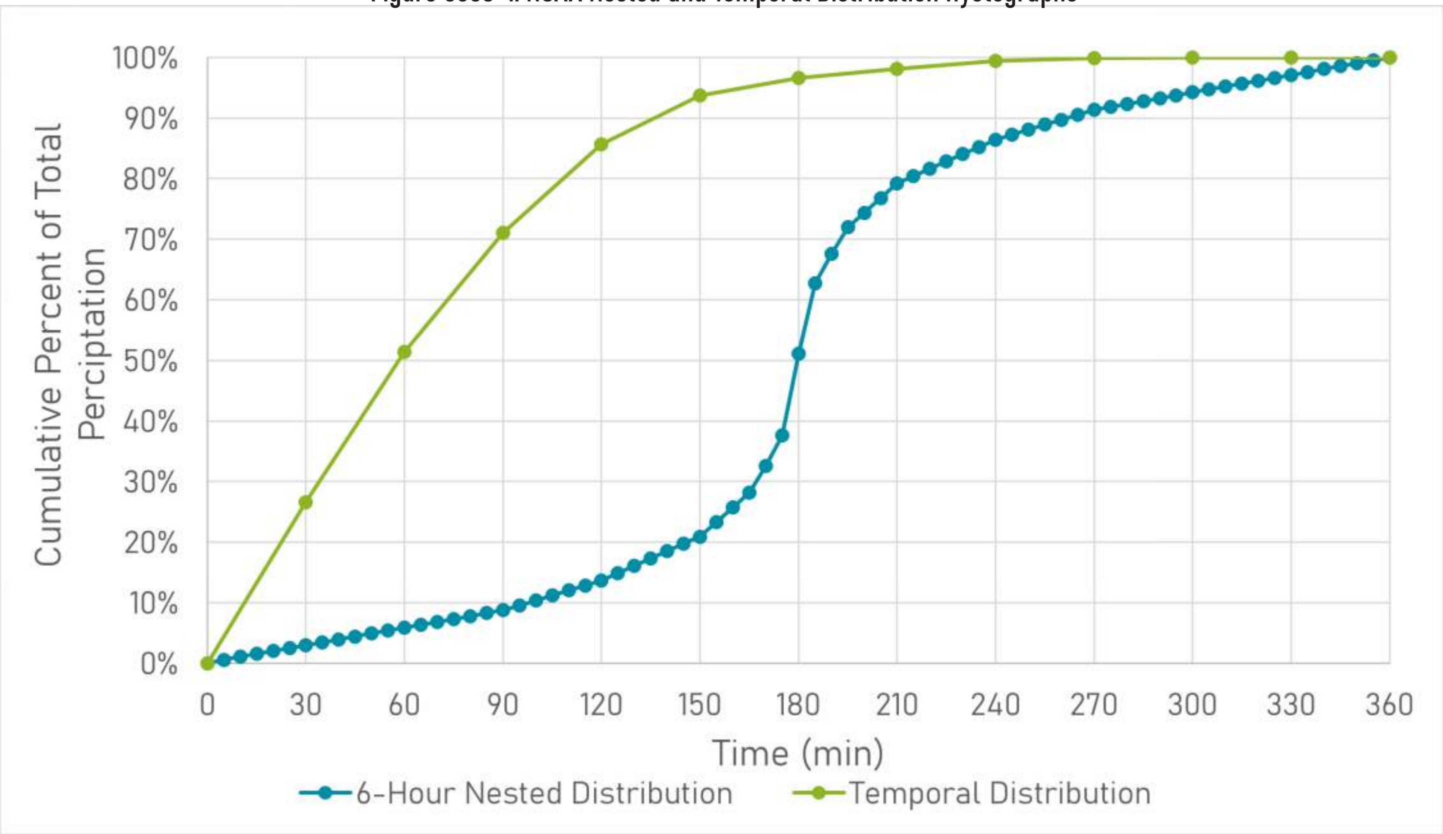
NOAA 6-Hour Storm Events

The National Oceanic and Atmospheric Administration (NOAA) serves as the basis for the rainfall data for the region and is intended to represent the latest available rainfall data. The 6-hour rainfall depths were developed using an average of the NOAA rainfall volumes over the nine-county MARC region. The rainfall volumes by return frequency are provided in **Appendix C**, Table C-1, and shall be used for the design of detention, collection, and conveyance components of the storm drainage system.

B. Rainfall Distributions

Rainfall distributions are based on the NOAA rainfall data. The following subsections define rainfall distributions to be used for detention, collection, and conveyance components of the storm drainage system. Collection and conveyance components will use a **nested distribution**, while retention and detention practices will use a **temporal distribution**, depicted graphically in Figure 5603-1.

Figure 5603-1: NOAA Nested and Temporal Distribution Hyetographs



* Generalized Nested distribution based on the 10hr 6yr rainfall intensities in the MARC region. This distribution was selected based upon appropriateness for the MARC region and should be evaluated for use outside of this region.

* The NOAA Temporal Distribution was developed for NOAA Atlas-14 Volume 8, Temporal Distribution Area 3.

Nested Distributions – Collection & Conveyance

A **nested distribution** (also known as an alternating block distribution) based on NOAA annual maximum precipitation frequency estimates shall be used for runoff calculations to collection and conveyance components of the storm drainage system. The nested distribution shall be a centered (50%) distribution with a 6-hour duration. Nested distribution hyetographs were developed from precipitation averages for the MARC region. The nested distribution hyetographs are constructed with a 5-minute timestep to capture the peak rainfall intensity. A graph of the NOAA nested distribution hyetograph is shown in Figure 5603-1 and is defined in **Appendix C**, Table C-2.

Temporal Distribution – Retention & Detention

The NOAA **temporal distribution** shall be used for runoff calculations to stormwater detention and retention facilities. The NOAA temporal distributions are provided in **Appendix C**, Table C-3.

C. Climate Non-Stationarity

Rainfall patterns and intensities have shifted between now and the previous century and represent an example of climate non-stationarity. Adoption of the NOAA Atlas-14 brings rainfall, runoff, and hydrologic guidance for the MARC region in line with the best available data on rainfall driven runoff responses. It is expected that NOAA will release an Atlas-15 that will provide projected future rainfall volumes. Before adopting Atlas-15 projected rainfalls, communities are recommended to consider measures which appropriately address anticipated future rainfall volumes and patterns and which fit within the context of the respective community.

Referred to as 'adaptation strategies', these measures address potential impacts caused by anticipated increases in rainfall and changes to rainfall patterns. These can include the construction of green infrastructure in built-out areas which are predicted to have increased risk of inundation, design of stormwater conveyance to accommodate increased flows, and dedication of undeveloped native lands with high quality vegetation and habitat to promote natural hydrologic processes.

Ideally these strategies are implemented in a manner which complements existing infrastructure, promotes the health of natural systems, and which mitigate future financial and community impacts. It is recommended that each community review the MARC Climate Adaptation Plan (**https://www.marc.org/environment/environment-plans/climate-action-plan**), study potential impacts caused by anticipated rainfall changes, and identify specific strategies, measures, and any necessary projects needed to achieve climate resilience goals. The EPA report 'Stormwater Management in Response to Climate Change Impacts: Lessons from the Chesapeake Bay and Great Lakes Regions' (2016) includes case studies and guidance for creating stormwater climate adaptation plans.

5603.3 RUNOFF GENERATION METHODS

Runoff volumes, peak discharge, flow rates, and hydrographs can be calculated in multiple different ways depending on the level of detail and the parameters required for design. Hydrologic and hydraulic simulation software packages are generally acceptable as long as the equations used therein meet the requirements and intent of this criteria.

For areas where offsite drainage enters the project site, the entire drainage area, including the offsite portion shall be accounted for in hydrologic calculations. This may be accomplished by modeling the offsite areas or, where other studies exist, using those studies to understand and account for the impact of offsite drainage.

Methods to simulate rainfall-runoff processes refer to the specific hydrologic equations used to estimate runoff volume and runoff flow rates. Runoff generation methods can range from simple with high degrees of uncertainty to complex where uncertainty is dependent on model parameterization, appropriate application of the method, the quality of the input parameters, and model calibration.

A. Hydrograph Methods

Except in the limited circumstances listed in **5603.4**, hydrograph-based hydrologic calculations shall be used. These methods have three primary components:

1. Loss method to determine excess precipitation (runoff)
2. Hydrograph transformation method to determine shape of the hydrograph
3. Channel routing method to lag and attenuate the hydrograph as it moves downstream

The following subsection describes preferred loss, transform and routing methods.

Allowable Loss Methods

Table 5603-2 defines the allowable runoff generation methods for varying applications. Other loss methods are allowable when approved by the regulating jurisdiction.

Table 5603-2: Allowable Loss Methods

Runoff Computation Method	Allowable Applications
NRCS Curve Number Method*	Acceptable for all applications
Green-Ampt	Acceptable for all applications
Horton	Acceptable for all applications
Rational Method	Acceptable for drainage areas less than or equal to 40 acres when only peak flow rates are needed.
2D Rain-on-Mesh Modeling	Acceptable for all applications in combination with another appropriate method to simulate infiltration/ runoff processes. Described further in **Section 5603.4**.

*For most applications, the NRCS Curve Number Method is the preferred loss method of this manual. Specific use cases may dictate that more complicated or detailed methods be used. Two specific use cases where a more detailed method may be needed are complicated watersheds where the flow path is unclear (and a 2D model may be needed), or a long-term continuous simulation to understand the water budget for wetland design (where soil wetting and drying processes must be accounted for and NRCS Curve Number method is not appropriate for continuous simulations).

NRCS Curve Number Method

The NRCS Curve Number (CN) method is the preferred method to calculate runoff volume. When combined with an appropriate transform method such as the NRCS Unit Hydrograph method the runoff volume can be transformed into an outflow hydrograph. The NRCS Curve Number Method requires the following input parameters to calculate runoff volume:

- Curve Number
- Antecedent Soil Moisture Condition
- Initial Abstraction

NRCS TR-55 shall be used as guidance for application of the NRCS Curve Number Method. The Curve Number method is only appropriate for single-event simulation and shall not be used for continuous simulations.

Post-Project Curve Number

Simplified land cover categories have been developed to determine post-project curve numbers for the project. Any soils within the proposed disturbance area shall assume a minimum Hydrologic Soil Group (HSG) C. Existing HSG C soils that are disturbed during construction shall assume HSG D. No soil disturbed by construction shall be assigned a HSG classification of A or B.

On projects with more than one land cover or soil type, an area weighted curve number shall be calculated using the curve numbers provided in Table 5603-3. Post-project Curve Number values to be used are defined in Table 5603-3 by land cover type and soil type. Other post-development curve numbers are not allowable without written approval by the appropriate approval jurisdiction.

Table 5603-3: Disturbed Area Post-Project Curve Number by Cover and Soil Types

Land Cover Type	Soil Type A CN	Soil Type B CN	Soil Type C CN	Soil Type D CN
Natural Areas	30	55	70	77
Pervious Areas	39	64	74	80
Impervious Areas	98	98	98	98
Solar Farm - Native	62	76	84	88
Solar Farm - Gravel	75	84	89	92
Gravel - Overflow Parking Lots, Trails/Maintenance Paths, and Substations	75	84	89	92
Gravel - Primary Parking Lots, Access Driveways, and Railroad Ballasts	88	92	94	96
Gravel - Public Road with Compacted Subgrade Materials	98	98	98	98
Artificial Turf - No Underdrain System	66	78	85	89
Artificial Turf - Underdrain System	88	92	94	96
Water Surfaces	100	100	100	100

*All non-impervious areas should fall into the "pervious" land cover type, unless land cover is one of the solar, gravel, or artificial turf cover types defined herein.

Antecedent Soil Moisture Conditions

Antecedent Moisture Condition (AMC) refers to the soil moisture state of a watershed before a rainfall event. Higher values of AMC increase the curve number relative to lower values of AMC to reflect how soil moisture prior to a rainfall event affects the infiltration capacity and runoff potential of the soil during rainfall. The NOAA Atlas-14 Nested 6-hour 50% storm hyetograph was selected for use with an AMC value of 2.0 in the MARC region. NRCS Curve Numbers provided in this manual are given for an AMC value of 2.0.

Initial Abstraction

Initial Abstraction (Ia) is the total amount of rainfall that is intercepted by surface storage, vegetation interception, and other processes before runoff begins. Initial abstraction in the NRCS Curve Number method for post-development conditions shall be calculated as follows:

Equation:

$$I_a = X * \left[\frac{1000}{CN} - 10 \right]$$

I_a = Initial abstraction (in)

X = { 0.20 for pre-development conditions; 0.05 for post-development conditions

CN = Curve Number

Green-Ampt Infiltration

Green-Ampt Infiltration is a robust physically based method of calculating infiltration that simplifies the soil wetting front as a hard line between initial soil conditions and wet soil conditions. Good guidance on appropriate infiltration parameters for different soil textures is available from other resources and should be consulted when applying Green-Ampt infiltration. Green-Ampt Infiltration is allowable for all applications.

Horton Infiltration

The Horton Infiltration method is a method of calculating infiltration and runoff during storm events. The Horton Infiltration method is allowable for all applications but is not preferred by this criteria owing to the lack of guidance on infiltration parameters for various soil.

Runoff Transform Methods

When combined with an appropriate transform method, such as the NRCS Unit Hydrograph Method, the runoff volume can be transformed into a runoff hydrograph. A runoff hydrograph includes the total runoff volume, runoff flow rates, and the total time that runoff occurs. A transform method must be applied to convert the rainfall volumes to hydrographs defining flow rates for each time step.

Table 5603-4: Allowable Runoff Transform Methods

Runoff Transform Method	Allowable Applications
NRCS Unit Hydrograph	Acceptable for all applications (Preferred Method)
Clark Unit Hydrograph	Acceptable only for basins with multi-year stream gauge data for existing condition model runs.
Snyder	Acceptable only for basins with multi-year stream gauge data for existing condition model runs.
Non-Linear Reservoir Routing (SWMM Runoff)	Acceptable for all applications

NRCS Unit Hydrograph Method

- The following model implementations of the unit hydrograph method are acceptable for all watersheds: SCS Technical Release No. 55 "Urban Hydrology for Small Watersheds", 2nd Edition, June 1986.
- SCS Technical Release No. 20 "Project Formulation – Hydrology", 2nd Edition, May 1983.

The unit hydrograph method requires lag time inputs as defined in **Section 5603.4, D**.

Clark Unit Hydrograph

The Clark Unit Hydrograph method is a unit hydrograph method that relies on the time of concentration and a watershed storage coefficient. These parameters can be estimated using GIS data but often vary depending on rainfall intensity. Where multi-year stream gauge data is available to estimate parameters and validate model results, the Clark Unit Hydrograph method is allowable for existing conditions modeling. An example of a use case where the Clark Unit Hydrograph method may be appropriate is for offsite drainage onto a project site where data exists to establish a watershed storage coefficient.

Snyder Unit Hydrograph

The Snyder Unit Hydrograph is a unit hydrograph method that relies on the basin lag time and a peaking factor. Determination of the parameters needed for the Snyder Unit Hydrograph can be done using Geographic Information System (GIS) software and an analysis of multi-year stream gauge data. Where quality, multi-year stream gauge data is available, the Snyder Unit Hydrograph method is allowable for existing conditions models. An example of a use case where the Snyder Unit Hydrograph may be appropriate is for offsite drainage onto a project site where data exists to establish a peaking factor.

Hydrologic Open Channel Routing Methods

Hydrologic routing utilizes simplified solutions of the Saint-Venant equations to route hydrographs and calculate flows efficiently. However, these methods may not reliably calculate stage and should be verified with hydraulic calculations as required by **Section 5608.1** where accurate channel stages are needed.

The following hydrologic open channel routing methods are allowed:

Table 5603-5: Allowable Channel Routing Methods

Channel Routing Method	Allowable Applications
Muskingum-Cunge	Preferred method
Kinematic Wave	Allowable for channels that have regular, well-defined geometry and limited overbank areas, where the effect of channel storage is minimal
Modified Puls	Method appropriate for open channels where embankments create incidental detention within the channel

Muskingum-Cunge Routing

The Muskingum-Cunge routing method uses the continuity equations and a simplified version of the momentum equations to calculate hydrograph routing through river reaches. The Muskingum-Cunge routing method is the preferred method to calculate channel routing, especially for natural channels and channels with drainage area greater than 20 acres.

Kinematic Wave

The Kinematic Wave routing method uses a simplified version of the unsteady flow equations to calculate hydrograph routing through river reaches. The Kinematic Wave method is appropriate for short reaches and where momentum and local acceleration forces are negligibly important. Users of the Kinematic Wave method should consult relevant documentations on parameter calculation and the application of Kinematic Wave routing.

Modified Puls

If the detention effect of significant storage in channels behind roadway embankments or culverts is to be modeled, the area impacted by the storage shall be modeled as a reservoir, and the remainder of the channel modeled using Muskingum-Cunge. Such incidental detention shall not be used for design discharge estimates unless allowed by the jurisdiction and it can be reliably demonstrated, through maintenance agreements or other forms determined by the jurisdiction, that such storage will be maintained over the useful life of the proposed improvements.

B. Time of Concentration & Lag Time

Lag time and time of concentration are used to characterize the time disparity between rainfall and runoff at the outlet of a drainage area. Where watershed transform calculations require them, lag time and time of concentration values shall be calculated using appropriate methods. In no instance is an assumed value for either lag time or time of concentration permitted for use in a hydrologic calculation. Time of Concentration shall be calculated in accordance with guidance in chapter 3 of the NRCS TR-55.

Equation #1:

$$T_c = T_{t1} + T_{t2} + \ldots + T_{ti} + \ldots T_{tm}$$

Equation #2:

$$T_{ti} = \frac{L_i}{V_i}$$

T_c = Time of concentration
M = The number of flow segments
T_{ti} = Travel time for the ith point in the drainage area
L_n = Length of the drainage path between the nth point in the drainage area and the outlet
V_n = Length weighted velocity between nth point and the outlet

Lag time is the difference between the center of mass of excess precipitation and the peak runoff at the outlet of the drainage area. In small natural watersheds the lag time may be estimated from the Time of Concentration as follows (NRCS National Engineering Handbook):

Equation #3:

$$T_{lag} = 0.6 * T_c$$

T_{lag} = Lag time

In watersheds with greater than 3% impervious landcover, the lag time shall be calculated using the following equation (Kansas Department of Transportation Report Number KS-16-01 by McEnroe et al. 2016). This equation is only applicable for the MARC region. For most applications, this is the preferred method of this manual. Methods described by McEnroe et al. 2016 are also allowable for small natural watersheds and engineers should reference et al. 2016 for guidance on application to regions outside of the MARC Region.

Equation:

$$T_{lag} = k * \left(\frac{L * (1 - 0.75 * R_c)}{\sqrt{S}}\right)^{0.87} * (W * (1 + 2.0 * R_i))^{-0.26}$$

T_c = 0.0112 (calibration (and conversion) coeffcient for the MARC region only)
L = Length of the longest flow path (ft)
R_c = the fraction of the main-channel that is paved or enclosed (dimensionless)
S = average slope of the longest flowpath (ft/ft)
W = Watershed Area divided by L (ft^2/ft)
R_i = the fraction of the watershed area that is impervious (dimensionless)

5603.4 RATIONAL METHOD

The Rational Method may only be used to calculate a peak runoff rate to collection and conveyance components of the storm drainage system under the following circumstances:

- When the total upstream area tributary to the point of consideration is less than 40 acres.
- For unmanaged drainage areas where stormwater is not retained or detained
- For calculating the inflow to a single drainage element, such as a culvert or single inlet.

The Rational Method is calculated as follows:

$$Q = K * C * i * A$$

Q = Peak rate of runoff (cfs)

K = Dimensionless coefficient to account for antecedent precipitation as follows, except the product of C and K (C*K) shall not exceed 1.0.

Design Storm	K
≤ 10-year	1.0
25-year	1.1
50-year	1.2
100-year	1.25

C = Runoff coefficient representing the fraction of rainfall that becomes runoff. Runoff coefficients are defined in Table 5603-7. In the absence of a suitable land use in Table 5603-7, the runoff coefficient may be calculated by the following equation:

$$C = 0.3 + 0.6 * I$$

I = percent impervious

i = Rainfall intensity defined in Table 5603-6 for a duration equal to the time of concentration defined in **Section 5603.4, D** (in/hr)

Table 5603-6 Metro Averaged NOAA Atlas-14 Rainfall Intensities (in/hr) for use with the Rational Method

Time of Concentration	2-year	5-Year	10-Year	25-Year	50-Year	100-Year
5 min	5.2	6.9	8.2	9.9	11.3	12.6
10 min	3.8	5.1	6.0	7.3	8.2	9.2
15 min	3.1	4.1	4.9	5.9	6.7	7.5
30 min	2.2	2.9	3.5	4.2	4.8	5.4
60 min	1.5	1.9	2.3	2.8	3.2	3.6

A = Drainage area (acres)

Rational Runoff Coefficient "C"

The Rational Method "C" value accounts for land cover type, soil infiltration parameters, and initial conditions to represent the fraction of rainfall that becomes runoff. For basins with different land cover types a composite "C" value shall be used. For basins where there is variability in land cover, an alternative approach to hydrologic analysis should be employed.

When simulating pre-development conditions the runoff coefficient shall not exceed 0.30.

Table 5603-7: Rational Runoff Coefficient "C" Values

Land Use/Zoning	Average Percent Impervious	Rational Method "C"
Business		
Downtown Area	95	0.87
Neighborhood Area	85	0.81
Residential		
Single-Family Areas	35	0.51
Multi-Family Areas	60	0.66
Churches & Schools	75	0.75
Industrial		
Light Areas	60	0.66
Heavy Areas	80	0.78
Parks, Cemeteries	10	0.36
Railroad Yard Areas	25	0.45
Undeveloped Areas	0	0.3
All Surfaces		
Impervious: asphalt, concrete, roofs, etc.	100	0.9
Turfed & Undeveloped Areas	0	0.3
Open Water	100	1.0

5603.5 2D MODELING GUIDANCE

Two-dimensional (2D) modeling provides a powerful tool in evaluating runoff, particularly for projects with complex hydrology. A 2D model is acceptable and may be used to calculate flows using the NRCS Curve Number Method, Green-Ampt, and Horton methods.

Due to the extensive range of 2D modeling products available, this criteria does not attempt to lay out specific modeling requirements; designers seeking to use 2D modeling should consult the modeling software documentation for product-specific guidance on modeling. Instead, this manual will lay out guidelines for the use of 2D models.

2D models should be capable of performing hydrology and hydraulic calculations in accordance with the contents of this criteria. 2D models shall be built in a modeling software package that is designed for the intended modeling purpose. Within the modeling software the numerical solver shall be selected based on specific project conditions.

In general, runoff calculations should be conducted utilizing rainfall that falls directly onto a 2D mesh or grid This is also known as "rain on grid". The 2D mesh or grid should be sized per the guidance and capabilities of the specific modeling software; mesh or grid elements should be small enough to provide a reasonable level of detail while not being so small that model performance is adversely affected. Boundary conditions should be set corresponding to expected inflow/outflow conditions.

Model parameters, such as infiltration and roughness should be selected per the specific software and model requirements and should be selected in a manner that represents the project site and watershed conditions. Designer should provide documentation that demonstrates the chosen parameters comply with the requirements of this manual.

One-dimensional (1D) or 2D hydraulic components may be used for flow conveyance; however, the designer shall demonstrate that the selected method is appropriate for the specific project site, based on methodology guidance, standard practices, etc.. In general, enclosed systems will utilize 1D hydraulic routing components, whereas open channels may use either 1D or 2D components.

2D models shall be calibrated. Models should be calibrated to historical storm events using stream gages, flow meters, or other measurement devices. Where historical data is not available, calibration should be performed using a 1D runoff method described in Table 5603-4 of this manual.

Input data to the model shall be of adequate detail and sufficient spatial resolution to capture hydraulicly significant features. The 2D mesh shall be refined using breaklines such that high elevation points are enforced in the mesh and the DEM shall have sufficiently high resolution to capture important landscape features. The model domain extents shall be selected to minimize flow across the boundary. Where flow does cross the boundary, boundary conditions shall be used, or the model domain shall be extended to the point where boundary conditions have no effect on the area of interest.

5603.6 HYDROLOGIC VALIDATION

As a part of hydrologic analysis, validation is required. Validation in its simplest form is confirmation that model results are close to expected values based on observed data or other hydrologic models.

Whenever possible, hydrologic validation shall be performed by comparing and calibrating modeled flows to observed data and documented. Model verification may utilize measured discharge rates from a similar watershed normalized to tributary area.

Where observed data is not available, the designer shall calculate peak flows at each discharge point that concentrated stormwater leaves a project site using an approved hydrology method and compare the results to modeled results to demonstrate reasonable agreement.

5604

DESIGN CRITERIA FOR PRESERVATION & RESTORATION

5604 PRESERVATION & RESTORATION

5604.1 PERFORMANCE REQUIREMENTS

As defined in **Section 5602**, identifying opportunities for **preservation** and/or **restoration** of **natural areas** within a dedicated tract of land restricted from future development can reduce the overall stormwater management requirements for a project. This process recognizes the stormwater management and ecological benefit that natural areas provide and therefore prioritizes and incentivizes preservation and/or restoration practices first.

Table 5604-1 summarizes the preservation and/or restoration performance requirements. Design calculations for these practices can be found in **Section 5602.3 A**. With the exception of **stream setbacks**, preservation and/or restoration of natural areas is not required as a part of project but doing so will reduce a project's **required retention volume (RRV)** and **detention** requirements. Stream setback preservation requirements are described in **Section 5608**.

A. Stream Preservation and Setbacks

Recommended Approach

It is recommended that communities adopt comprehensive stream preservation and setback requirements as part of their comprehensive plan, ordinances, and codes and enforce those policies during the planning phase of land development. Requirements may be selected to protect environmental and quality of life benefits and be tailored to local geography and natural resources. The width of setbacks may be adjusted to reflect local experience with stream discharge, floodplain width, stream migration and stability, protection of adjacent wetlands or critical habitat, or water quality treatment.

Natural streams should be preserved as systems and not segmented on a project-by-project basis, as the frequent intermixing of natural and man-made systems tends to degrade the function of both.

Default Approach

Where such comprehensive strategies have not been adopted, the following requirements shall be satisfied for all improvements proposed adjacent to or ultimately discharging to an existing **natural channel**:

- Streams having a tributary area more than 20 acres shall be preserved along with adjacent setbacks. For work on existing facilities already located within the required stream setback, the disturbed area shall not increase the encroachment any closer to the stream unless authorized by the approving jurisdiction. Preservation of smaller streams is encouraged. Preservation of streams with a tributary area between 20 and 40 acres may be waived by the approving jurisdiction where it results in the property being substantially undevelopable for the landowner provided that the landowner provides at least a functional equivalency of the existing system in the same drainage area that includes the same setback minimums, and the replacement system is clearly in the public interest; also provided that the project has received appropriate state and federal permits.

- The limit of setback zones shall be formally designated on a plat, deed, easement, or restrictive covenant, as directed by the approving jurisdiction. Setback widths shall exceed the dimensions shown in Table 5604-2. Setbacks shall be established for all preserved streams by the following designated zones:

  1. **Zone 1 (Streamside Zone)**: area immediately adjacent to the stream is preserved for frequent stormwater flows and shall include dense stands of native vegetation. With the exception of allowable uses, Zone 1 must be preserved or restored according to the specifications in **Section 5604.2 A** and/or **5604.3 A**. Allowable uses include utility and road crossings only. The setback zone is measured from the top of bank of the channel outward to the designated setback. If the top of bank cannot be determined, the channel extents may be defined as the bank-full or channel-forming flow caused by the 2-year design storm.

  2. **Zone 2 (Preservation Setback)**: is intended for natural area preservation and native vegetation to provide protection against more extreme flood events. With the exception of allowable uses, Zone 2 must be preserved or restored according to the specifications in **Section 5604.2 A** and/or **5604.3 A**. Allowable uses also include linear utility corridors, linear trails, and open-sided structures that do not impede stormwater drainage. Zone 2 extends a defined distance from the edge of Zone 1, or, to the extents of the 1% annual chance of exceedance flood (as defined by engineering calculations or FEMA flood maps) plus an additional defined distance, whichever is greater.

Figure 5604-1: Preservation & Restoration Performance Requirements & Incentives

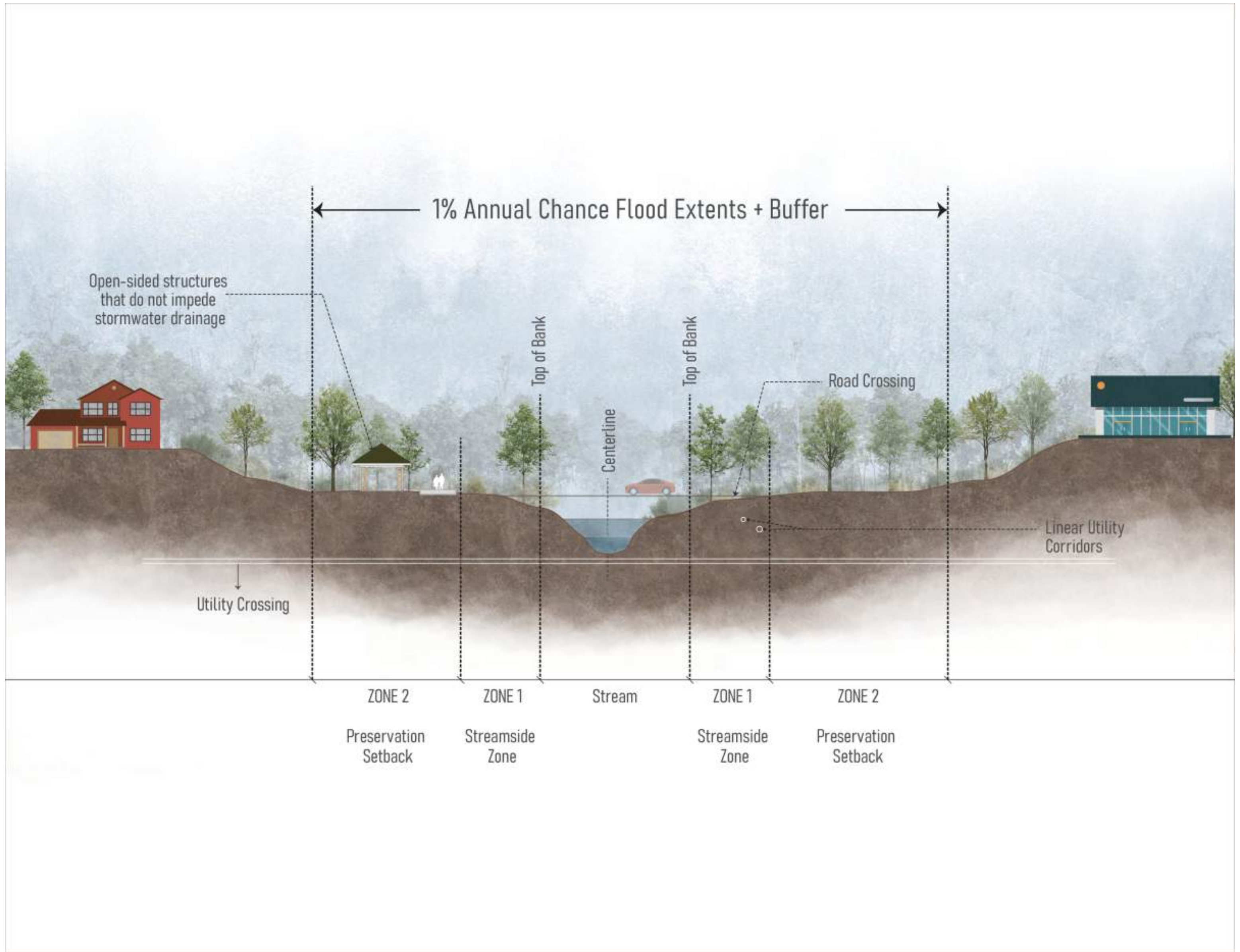


Table 5604-2: Stream Setback Widths

Drainage Area Range	Zoned Setbacks	Zone Wdith	Development Allowed Within Zone	Exceptions
40+ acres (required)	Zone 1 Streamside Zone	25-feet from top of bank	Utility crossings & roadway crossings	None
	Zone 2 Preservation Setback	1% annual chance of exceedance flood extents plus an additional 25-feet	Linear utility corridors; linear trails; open-sided structures that do not impede stormwater drainage	
20 acres to less than 40 acres (required)	Zone 1 Streamside Zone	10-feet from top of bank	Utility crossings & roadway crossings	Channel modifications or relocation allowed where results in the property being substantially undevelopable for the landowner provided that the landowner provides at least a functional equivalency of the existing system in the same drainage area that includes the same setback minimums, and the replacement system is clearly in the public interest
	Zone 2 Preservation Setback	Whichever is greater: 50-feet from Zone 1, or 1% annual chance of exceedance flood extents plus an additional 10-feet	Linear utility corridors; linear trails; open-sided structures that do not impede stormwater drainage	
10 acres to less than 20 acres (recommended)	Zone 1 Streamside Zone	5-feet from top of bank	Utility crossings & roadway crossings	Major modifications allowed to include engineered channel allowed if natural channel design would preclude reasonable project or infrastructure options.
	Zone 2 Preservation Setback	45-feet from Zone 1	Linear utility corridors; linear trails; open-sided structures that do not impede stormwater drainage	

* Measured outwards separately in each direction

- The approving jurisdiction may require wider setbacks for less stable streams or special conditions to address flood risk, potential infrastructure or structure conflicts, water quality, and ecological needs. The widths in Table 5604-2 provide only moderate allowance for widening or migration in local streams of average stability. In some cases, the bankfull channel will migrate and erode the setback over time, reducing or eliminating setback protections. For this reason, the setbacks should be considered minimum zones of stream protection and the minimum exclusion corridors for asset placement. Careful site-specific attention by a qualified fluvial geomorphologist should be paid to the width of the meander belt of the system as that is the common functional erosion risk zone in systems with naturally migrating channels. Geotechnical studies may be required if there is a risk of slope failure due to underlying soil or rock materials, and the setback width shall be expanded to contain the zone of failure.

- No construction or disturbance of any type, including clearing, grubbing, stripping, fill, excavation, linear grading, paving, or building is allowed in the Zone 1 and Zone 2 setback areas except by permission of the approving jurisdiction. Such impacts must be determined to be essential, unavoidable, and minimized. Avoidance and minimization do not necessarily apply where stream restoration with natural channel design are permitted for a historically and adversely impacted reach and where the stream restoration is in the public interest.

5604.2 PRESERVATION PRACTICES

Preservation of natural features is an important part of managing stormwater. Since **natural areas** and existing trees are better able to absorb stormwater runoff than developed lands, preservation of natural areas and trees will reduce a project's **retention** and **detention** requirements.

A. Preserved Natural Area

Description

Preserved natural areas on a site at a minimum are assigned a runoff coefficient of zero, meaning that they do not contribute to the retention volume requirements for a project site. These areas are therefore, typically excluded from the **disturbed area** and not considered a part of the project site.

As a part of a carefully designed project, preserved natural areas can accommodate sheet flow runoff from parts of the project site, reducing both runoff volume and associated pollutants. Preserved natural areas include areas of trees, saplings, shrubs, and herbaceous undergrowth. Their composition, density, and age structure may vary, but in general they must be composed predominantly of native plant species. Preserved natural areas may include forests, woodlands, wetlands, grasslands, and other native plant communities.

Design Criteria & Performance Requirements

In order to qualify as a preserved natural area or to be credited with reductions to the **required retention volume (RRV)**, preserved natural areas must meet the following design criteria and performance requirements:

- **Preserved in Perpetuity**. Natural areas must be placed under covenant, in an easement, in a restricted lot, or other similar restriction that preserves the area from future development or disturbance.

- **Sufficient Area**. In order to avoid habitat fragmentation and minimize stand-alone pockets, individual natural areas must be at least 1/2 acre in contiguous area and have a minimum length and width of at least 50 feet. The total combined areas of all natural areas preserved or restored at the site must be at least 1 acre.

- **Protected from Disturbance**. If natural areas are not receiving stormwater runoff from the project site, they may be excluded from the disturbed area. Natural areas receiving sheet flow runoff must be included in the disturbed area calculations of a project as they will effectively function as a retention practice, but they must be excluded from construction impacts. Safety fencing as well as appropriate internal control, protection, and stabilization measures per Section 5606, GSI-11 must be installed to protect and preserve natural areas during construction.

- **Receiving Runoff**. The following requirements apply to preserved natural areas designed to receive sheet flow runoff only:

  - **Gentle Slopes**. The maximum average slope of the natural area receiving sheetflow runoff is 5%. There are no limits on the maximum slope for preserved natural areas if they are not receiving runoff from the development.

  - **Predominantly Native Vegetation**. A preserved natural area in the Kansas City metro area will most likely be in the form of a woodland or grassland. The predominant vegetative cover of these natural areas must be comprised of at least 75% native plant species or less than 25% cover of invasive exotic species. For example, a preserved woodland comprised of at least 75% native canopy trees would be eligible for preservation. Likewise, a grassland comprised primarily of native grasses and herbaceous perennials would also be eligible. Areas in which significant invasive species control is necessary are not eligible for preservation, but may be considered for restoration. Where necessary, enhancement plantings of native species that promote infiltration, ecological improvement and sustainability may be specified, but all planting or seeding should primarily be done by hand to minimize the use of mechanical methods and limit disturbance.

» **Management Plan**. A long-term vegetation management plan must be provided to maintain the preserved area in a natural vegetative condition per **Section 5609**. Control of invasive weed species should be an integral part of the management plan. The management plan cannot include frequent mowing (more than twice a year), mulching, or other maintenance activities that would be needed for managed turf or other heavily landscaped areas.

Design Deliverable Checklist

The following items must be provided with any design that includes sheet flow runoff to a preserved natural area:

➔ Plan identifying topography, slope, and boundaries of preserved natural area, as well as the area sheet flowing to it, if applicable.

➔ Construction safety fence and GSI-11 internal control, protection and stabilization methods, and signage to protect area from disturbance.

➔ Vegetative field survey provided by a licensed landscape architect, certified professional forester, or certified professional ecologist documenting species diversity of the existing plant community.

➔ Vegetation management plan per Section 5609.

➔ Covenant or easement language preserving the area in perpetuity.

B. Tree Preservation

Description

When meeting the requirements for preserved natural areas is not feasible, individual trees may be preserved as a part of a project to reduce the required retention volume for the site. These trees may be located in a group within smaller undeveloped areas or individually throughout the development. Each preserved tree is assigned a runoff reduction volume.

Design Criteria & Performance Requirements

In order to be credited with retention value reduction, preserved trees must meet the following design criteria and performance requirements:

➔ **Minimum Diameter Breast Height**. (DBH) must be ≥ 6 inches at 4.5 feet above the ground, on the uphill side of the tree.

➔ **Tree Inventory**. All preserved trees, except those included in preserved natural areas must be identified in a tree inventory that includes the tree species, size (trunk diameter), and condition. For large acreages, plot sampling methods for the tree inventory may be acceptable depending on local jurisdiction requirements.

➔ **Not invasive**. While preserved trees do not need to be native, invasive trees, as determined by the approving jurisdiction cannot be counted for retention value reduction.

➔ **Protected from Disturbance**. Preserved trees must be included in the project's disturbed area but they must be protected from construction impacts, including excavation, fill, trenching, storage of construction materials, or disposal of liquids per GSI-7.8.

➔ **Tree Protection Plan**. If land disturbance is proposed within the **critical root zone** (CRZ), the tree may be counted for preservation only if a tree preservation plan is prepared and certified by a qualified professional. The tree preservation plan may include root pruning, matting, or other actions to limit impacts to tree health during construction.

Design Deliverable Checklist

The following items must be provided with any design that includes a preserved tree:

➔ Tree inventory prepared by a licensed landscape architect, certified professional forester, or certified professional arborist identifying all trees to be preserved.

➔ Tree protection plan and details per GSI-7.1

➔ Tree protection specification per specification section 02949.

5604.3 RESTORATION PRACTICES

Restoration of natural features can have a significant impact on the runoff characteristics and overall environmental value of an improvement project. Restored **natural areas** and planted trees are better able to absorb stormwater runoff than developed lands, and are therefore credited with reduction of a project's retention and detention requirements.

A. Restored Natural Area

Description

Restored natural areas may include forests, woodlands, wetlands, grasslands, and other native plant communities. Restored natural areas on a site at a minimum are assigned a runoff coefficient of zero, meaning that they do not contribute to the retention volume requirements for a project site.

Restored natural areas can be a key part of a stormwater management plan, and can be designed to accommodate sheet flow runoff from other parts of the project site, reducing both runoff volume and associated pollutants.

Design Criteria & Performance Requirements

In order to qualify as a restored natural area or to be credited with reductions to the required retention volume, restored natural areas must meet the following design criteria and performance requirements:

➔ **Preserved in Perpetuity**. Natural areas must be placed under covenant, in an easement, in a restricted lot, or other similar restriction that preserves the area from future development or disturbance.

➔ **Sufficient Area**. In order to avoid habitat fragmentation and minimize stand-alone pockets, individual natural areas must be at least 1/2 acre in area and have a minimum length and width of at least 50 feet. The total combined areas of all natural areas preserved or restored at the site must be at least 1 acre.

➔ **Soil Restoration**. Soil restoration involves deep tilling, grading, and soil compost amendments. Soil restoration is a required component of a restored natural area, unless:

» Existing soils have high infiltration rates (greater than 0.5 inches per hour)

» The water table or bedrock is located within 1.5 feet of the soil surface.

» Existing soils are saturated or seasonally wet

» Soil restoration would harm roots of existing trees to be preserved.

» Additionally, any slopes exceeding 5% within the restoration area would exempt from soil restoration.

➔ **Compost Amendments**. Soil compost amendments must be included as a part of soil restoration to achieve a minimum organic matter content of 5% to a depth of at least 6 inches. Soil testing for pH, organic content, and soil texture must be performed to determine what, if any, further soil amendments are needed. Compost shall meet the requirements of Section 02947.

➔ **Stable native plant community**. Restoration plantings must be designed by a licensed landscape architect, certified professional forester, or certified professional ecologist with the intention of creating a stable native plant community (at least 75% native species). While the species mix will vary based on the intended ecosystem, a diverse mix of native trees, shrubs, and herbaceous understory vegetation is recommended.

➔ **Planting Plan**. Vegetation restoration methods may include live planting, sowing seed, or a combination of both.

» Live planting minimum sizes:

› Minimum tree size: 1.5-inch caliper.

› Minimum evergreen tree size: 6-foot height

› Minimum multi-stem tree size: 8-foot height

› Minimum shrub size: number 3 container

› Herbaceous perennial plant size (plug, quart, or gallon) may vary depending on species

» Live planting density requirements:

› Shade trees: 20-foot to 30-foot spacing

› Evergreen trees: 10-foot to 20-foot spacing

› Ornamental trees: 10-foot to 20-foot spacing

› Shrubs: 5-foot to 10-foot spacing

› Herbaceous perennials: average 15 inches on center

» Seeding: Sow a diverse mix of warm-season and cool-season herbaceous plants. Include short-lived herbaceous plants for initial establishment and long-lived herbaceous plants for long-term establishment. Refer to **Appendix E Landscaping** for additional seed mix guidance.

» Vegetative coverage requirements for seeding:

› Within 1 year of seeding: 75% total plant cover, with 30% of cover in specified native plants.

› Within 2 years of seeding: 85% total plant cover, with 50% of cover in specified native plants.

› Within 3 years of seeding: 100% plant cover, with 75% of cover in specified native plants.

➔ **Erosion & Sediment Control/Internal Control, Protection & Stabilization**. The planting and vegetation management plans must meet erosion and sediment control as well as GSI-11 Internal Control, Protection and Stabilization standards for short-term and long-term vegetative stabilization.

» Erosion prone sites should be planted with a cover crop to provide initial vegetative cover and support establishment of the native plants.

» Steep slopes and areas subject to run-off should be stabilized with erosion control blankets.

➔ **Construction Sequencing**. Restored natural areas must be included in the disturbed area for a project, but construction must be sequenced such that once a restored natural area has been graded and planted, no further disturbance will occur in the area.

➔ **Management Plan**. A long-term vegetation management plan must be provided to maintain the restored area the designed vegetative condition. The management plan should provide guidance for both the initial plant establishment period (years 1-3) and long-term vegetation management (after 3 years). Control of invasive weed species should be an integral part of the management plan. The management plan cannot include frequent mowing (more than twice a year), mulching, or other maintenance activities that would be needed for managed turf or other heavily landscaped areas.

➔ **Plant Replacement**. Replacement of plantings as needed for at least three growing seasons must be included in the management plan.

➔ **Receiving Runoff**. The following requirements apply to restored natural areas designed to receive sheet flow runoff only:

» **Gentle Slopes**. The maximum average slope of the restored natural area receiving sheet flow runoff is 5%. There are no limits on the maximum slope for restored natural areas if they are not receiving runoff from the development

Design Deliverable Checklist

The following items must be provided with any design that includes sheet flow runoff to a restored natural area:

➔ Plan identifying topography, slope, and boundaries of restored natural area, as well as the area sheet flowing to it, if applicable.

➔ Soil test results (pH, % organic matter, and soil texture) and soil restoration plan.

➔ Planting plan, including species, size, and spacing.

➔ Erosion and sediment control considerations.

➔ Construction sequence incorporating restoration activities into overall construction plan.

➔ Construction safety fence and GSI-11 internal control, protection and stabilization methods to protect area from disturbance.

➔ Vegetation management and plant replacement plan.

➔ Covenant or easement language preserving the area in perpetuity.

➔ Management Plan

B. Tree Planting

Description

Tree planting is a common part of many development plans. Outside of restored natural areas, which are considered separately with regard to runoff reduction requirements, tree planting may be included on private properties, as a part of retention practices, in the public right of way, or in other common spaces. Each planted tree is assigned a volume to reduce the required retention volume (See Section 5604.3 A).

Design Criteria & Performance Requirements

In order to be credited with retention value reduction, planted trees must meet the following design criteria and performance requirements:

➔ **Tree Sizes**. The proposed tree species must be identified and be appropriate for the planting location and conditions.

» Minimum sizes:

› Minimum deciduous shade tree size: 2-inch caliper or approving jurisdiction minimum required size, whichever is larger.

› Minimum evergreen tree size: 6-foot height or approving jurisdiction minimum required size, whichever is larger.

› Minimum multi-stem deciduous tree size: 8-foot height or approving jurisdiction minimum required size, whichever is larger.

» **Rootable Soil Volume**. A minimum of 1,000 cubic feet of rootable soil volume must be provided per tree. Rootable soil is soil that is accessible to the planted tree, un-impeded by structures, and to a depth of at least three feet below the ground surface in which the tree is planted. For street trees in the right-of-way with demonstrated constraints, a minimum 600 cubic feet of soil should be provided to support good tree establishment and health. Propriety products like soil cells under sidewalks, parking lots, or roads are options to meet soil volumes. Additionally, the use of structural soil (GSI-5.1) is another alternative to meet soil volume needs.

» **Not Invasive**. While planted trees do not need to be native, invasive trees, as determined by the approving jurisdiction, should not be considered for planting and cannot be counted for retention value reduction.

» **Planting.** Refer to the approving jurisdiction for acceptable planting season guidelines.

Trees should be placed to avoid utility conflicts where possible. Watering during establishment to support the health of the trees should be provided by automatic irrigation or manual watering methods (use of tree bags).

Design Deliverable Checklist

The following items must be provided with any design that includes tree plantings receiving retention value reduction:

➔ Planting plan, including quantities, species, size, spacing, and delineation of rootable soil areas.

➔ Rootable soil volume calculations.

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5605

DESIGN CRITERIA FOR RETENTION & DETENTION

5605 DESIGN CRITERIA FOR RETENTION & DETENTION

Retention and/or **detention** is achieved through the use of **green stormwater infrastructure (GSI)** practices. GSI is a holistic approach to stormwater management that helps collect and store rainwater where it falls by mimicking the natural water cycle. Other terms often used for GSI include post-construction stormwater best management practices (BMPs), stormwater control measures (SCMs), nature-based solutions, stormwater treatment facilities (STFs), blue-green infrastructure (BGI) and more. Stormwater management techniques implemented to achieve retention and/or detention requirements are herein referred to as **GSI practices**.

GSI practices can come in many different shapes, sizes, applications, and materials but are typically generalized by practice types. GSI practices are built by assembling GSI components, found in **Section 5606**. GSI practices are introduced in this section, with the goal of identifying appropriate design components to support the intended function of the GSI. The following GSI practices are included in this section:

- **A.** Bioretention
- **B.** Permeable Pavement System
- **C.** Infiltration Trench
- **D.** Wetland
- **E.** Wet Detention Basin
- **F.** Dry Detention Basin
- **G.** Subsurface Storage
- **H.** Green Roof
- **I.** Blue Roof
- **J.** Cistern

This section includes the following subsections:

- ➔ **Performance Requirements**: calculations to size GSI practices to meet **required retention volume (RRV)** for retention and **required release rates** for detention
- ➔ **Retention & Detention Practices**
  - » **Description**: definition of the practice
  - » **GSI Storage & Sizing**: reference to the storage and sizing calculations applicable to GSI components appropriate for the practice
  - » **Design Considerations**: general considerations for design of the practice and its required/recommended components.
  - » **Typical GSI Components**: design considerations for each GSI component that is either recommended or required for the GSI practice

5605.1 PERFORMANCE REQUIREMENTS

A. Retention Design Calculations

Stormwater **retention** shall be required to manage runoff produced from the disturbed area for the **Water Quality Storm**. The **required retention volume** (RRV) shall be managed using retention practices. Retention volume requirements may be achieved independently or within a detention practice provided the retention volume is provided below the primary outlet structure.

GSI practices should be designed with the goal of reducing the volume of stormwater runoff and improving the quality reaching the downstream systems. GSI stores water in the void spaces within each component layer of a GSI practice.

> Stormwater retention performance requirements for different project types are described in **Section 5602.3**, Table 5605-1. Detailed criteria for designing retention practices can be found in **Section 5605.2**.

These component layers include the ponding area, growing media, storage aggregate media, storage chambers, or any combination thereof. Sizing GSI practices to store the RRV can be an iterative process, balancing site area, storage depth, and material porosity. Therefore, storage volume is a function of three variables of the GSI practice:

1. GSI Area
2. Storage Layer Depth
3. Media Porosity

The **retention storage volume** (V_R) of the GSI practice is the sum of the storage volume of the various component layers within the GSI practice multiplied by a runoff reduction factor. If **continuous monitoring and adaptive controls (CMAC)** technology is used to optimize storage and function of the GSI practice, the CMAC-controlled volume may be factored into the storage volume provided by the retention practice.

Each GSI practice has a calculated storage volume unique to its configuration. The total storage volume of the GSI practice should be greater than or equal to the RRV tributary to it, as defined in **Section 5602**. GSI practices may be designed in series such that the excess RRV from an upstream practice is routed to and controlled in a downstream practice.

Equation 5605-1:

$$V_R = GSI_{RRF} * GSI_{Storage}$$

- V_R = Retention storage volume provided by retention practice (ft³)
- GSI_{RRF} = The GSI runoff reduction factor that represents the portion of the GSI storage volume that provides the credited retention benefits (%)
- $GSI_{Storage}$ = Static storage volume provided by the GSI practice (ft³)

Equation 5605-2:

$$GSI_{Storage} = V_P + \sum V_m + V_s$$

- V_P = Open storage volume provided by the ponding layer within the retention practice (ft³)
- V_m = Media storage volume provided by the aggregate and/or soil media layer within the retention practice (ft³)
- V_s = Volume provided with the storage chamber layer within the retention practice, if applicable (ft³)

GSI Runoff Reduction Factor (GSI_{RRF})

The GSI runoff reduction factor represents the portion of the GSI storage volume that provides full retention benefits. GSI practices that rely solely on infiltration maximize the recognizable retention volume. GSI practices shall require controlled release of stormwater through an underdrain or outlet control structure unless in-situ infiltration testing shows that the required drawdown can be met without it. Underdrains will require an outlet control structure per GSI-9 (**Section 5606.9**).

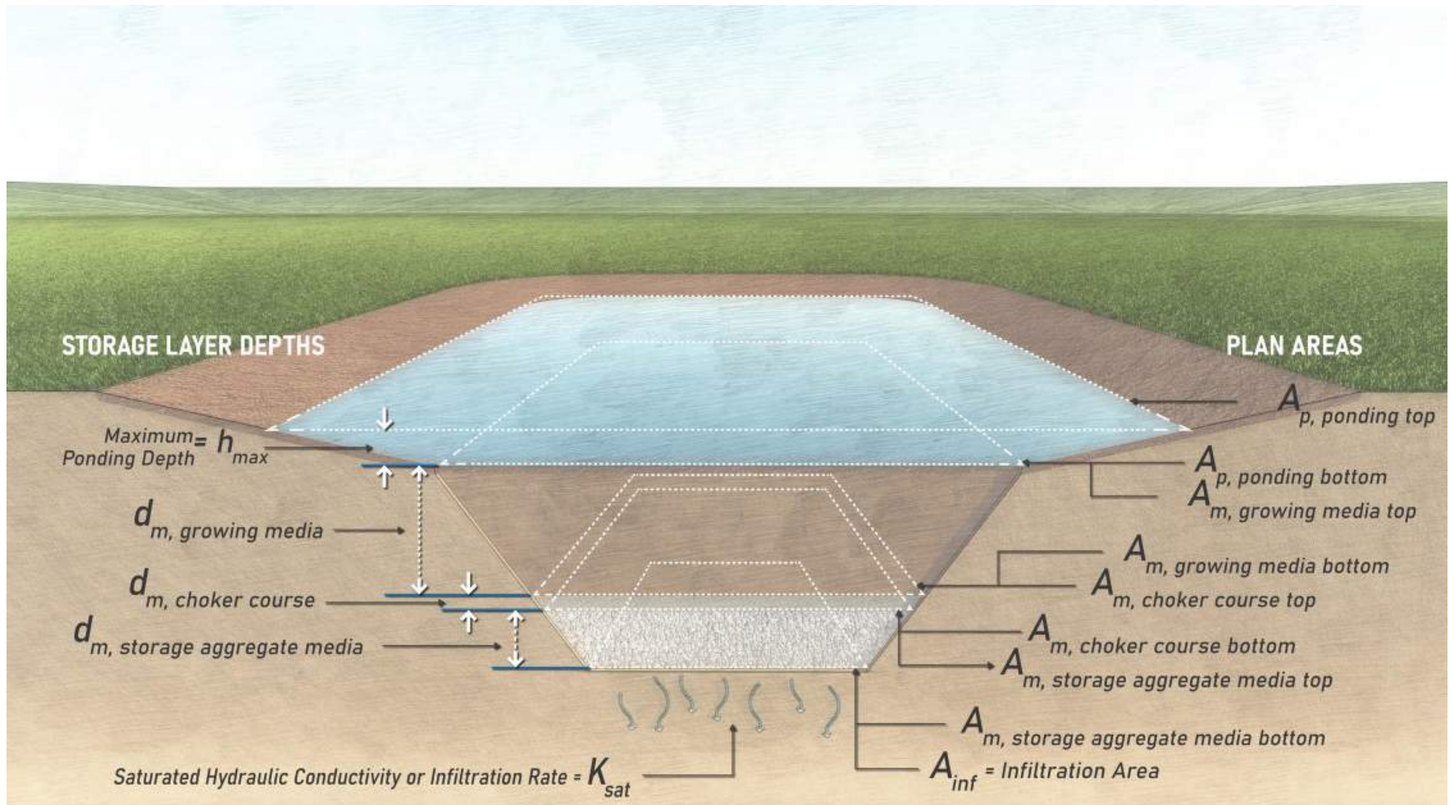
Table 5605-1: GSI Practice Runoff Reduction Factors

GSI Practice	Runoff Reduction Factor (Percentage)	
	Controlled Release (Underdrain/Outlet Control Structure)[2]	Infiltration Only
Bioretention	80%	100%
Permeable Pavement System	65%	100%
Infiltration Trench	65%	100%
Wetland	50%	-
Wet Detention Basin	10%	-
Dry Detention Basin[1]	60%	100%
Subsurface Storage	50%	100%
Green Roof	100%	-
Blue Roof	20%	-
Cistern	50%	-

[1] Retention allowed below outlet control structure only

[2] If continuous monitoring **and** adaptive controls (CMAC) technology is used, the CMAC controlled volume may be included in the provided retention storage volume calculation.

Figure 5605-1: Bioretention Storage & Sizing Calculations



Ponding Storage

Ponded storage is defined as the volume available for the retention or detention of stormwater above the surface of the GSI practice. Ponding storage volume can be calculated as the maximum ponding depth times the average ponding area, as follows:

Equation 5605-3:

$$V_P = A_{P,avg} * h_{max}$$

V_P = Ponding volume (ft³)

$A_{P,avg}$ = Average of top and bottom plan area of ponding (ft²)

H_{max} = Maximum ponding depth (ft)

Ponding depth is the height stormwater can reach within the GSI before overtopping or bypassing the facility. The maximum ponding depth should be limited based on constraints of the GSI practice. These constraints may include one or more of the following:

- Maximum allowable duration of surface ponding and saturated hydraulic conductivity of the subgrade soil that will limit this drawdown. The growing media soils shall have a saturated hydraulic conductivity greater than the dewatering infiltration rate calculated.
- Compaction of the growing media caused by the weight of the water
- Presence of an underdrain or dewatering system. An underdrain or dewatering system shall be required on all practices unless in situ infiltration testing validates that underlying soils meet the drawdown requirements for the GSI practice.
- Inundation tolerance of vegetation

Maximum ponding depth for GSI practices that are limited by maximum allowable duration of surface ponding as a function of the infiltration rate of the subgrade/in-situ soil shall be calculated as follows:

Equation 5605-4:

$$h_{max} = \frac{t_{max} * i * A_{inf}}{A_{P,avg}}$$

h_{max} = Maximum ponding depth (ft)

t_{max} = Maximum allowable duration of surface ponding (hours)

i = Average infiltration rate of subgrade soil measured according to an accepted test, as described in Specification Section 02956. Saturated hydraulic conductivity (k_{sat}), if available, may be substituted for i (ft per hour).

A_{inf} = Infiltration area as measured in the horizontal plane, where GSI Practice ponding or media layer is in contact with subgrade or in-situ soil (ft²)

$A_{P,avg}$ = average of top and bottom plan area of ponding (ft²)

Soil & Aggregate Media Storage

Media storage is defined as the volume available for the retention or detention of stormwater within the voids of the soil or aggregate media component of the GSI practice. The storage volume for soil and aggregate media should be calculated using the following equation:

Equation 5605-5:

$$V_m = A_{m,avg} * d_m * n$$

V_m = Media storage volume (ft³)

$A_{m,avg}$ = Average of top and bottom plan area of media layer (ft²)

d_m = Depth of media layer (ft)

n = Porosity of media (unitless, decimal)

- This equation determines the volume based on the plan area and media depth, accounting for the media porosity to calculate the storage volume within the media. See GSI-5 Soil & Aggregate Media (**Section 5606.5**) for recommended porosity assumptions for various soil and aggregate media.
- The total media storage volume of a GSI practice is equal to the sum of the storage volume of each respective media layer.

Storage Chamber Layer

Volume calculations for storage chambers are specific to the manufactured product selected and should follow manufacturer guidelines for sizing of the GSI component. Subsurface storage may also include additional storage volume in storage aggregate media layers around the storage chambers, as applicable. In this scenario, the storage volume for soil and aggregate media should be calculated using Equation 5605-5. However, some manufacturers of storage chamber products will provide storage volumes that include the storage aggregate media backfill and bedding materials. In this scenario, the designer should follow manufacturer guidelines.

B. Detention Design Calculations

Detention storage volume is required to offset the increase in runoff rates from typical rainfall events. The required release rates are set to control the release for the smaller, more frequent storm events through the **primary control structure** while allowing larger, less frequent events to safely pass through the facility without overtopping the **secondary control structure**. Peak runoff control shall be provided for a range of design storms to provide broad protection of the receiving system and downstream communities, including channel erosion protection and peak flood reductions. Design storms for detention shall be based on the NOAA Temporal Distributions as defined in Section **5603.2**.

Stormwater detention performance requirements are defined by project type in Table 5602-6 (**Section 5602.3**). Detailed criteria for designing detention practices can be found in **Section 5605.2** Retention & Detention Practices.

5605.2 RETENTION & DETENTION PRACTICES

A. Bioretention

Description

Bioretention are depressed planting beds that can capture, store, and treat stormwater runoff through a variety of pollutant removal processes including infiltration, transpiration, filtration, biological and microbiological uptake, and soil adsorption. Layers of growing media and/or aggregate store the water, allowing it to infiltrate into the adjacent subgrade or evapotranspirate with the help of deeply rooted native vegetation. An underdrain may also be included to drain excess stormwater, controlling the slow release of the collected stormwater back to the receiving system. Bioretention **GSI practices** come in a variety of shapes and sizes, such as basins in open areas, linear or sloped applications along roadways, or even engineered tree planters that provide a stormwater management function.

Bioretention can be used in a variety of applications that provide the same or similar functions, including:

- **Bioretention basin**: typically a larger footprint applied in an open area with sides sloped to create the storage depression
- **Rain garden**: simplified bioretention practices with limited GSI components mainly relying on existing or amended native soil media and landscaping for stormwater management.
- **Bioswale**: bioretention applied on a sloped application with stepped pools or check dams to create storage areas
- **Bioretention planter**: smaller footprints applied in roadside, parking lots, or plaza applications typically with vertical curbs or walls to create a shallower storage depression.
- **Stormwater tree planter**: bioretention planters that utilize trees as the primary vegetation.

GSI Storage & Sizing

Bioretention provides stormwater storage in the ponding, growing media, and/or storage aggregate media layers. **Retention** volume provided by bioretention GSI storage is calculated as the total storage volume for each of its storage components, as follows:

Equation 5605-6:

$$V_{GSI\ Storage} = V_P + V_{m,\ growing\ media} + V_{m,\ choker\ course} + V_{m,\ storage\ aggregate\ media}$$

V_P = Ponding volume

$V_{m,\ growing\ media}$ = Media storage volume of growing media

$V_{m,\ choker\ course}$ = Media storage volume of choker course

$V_{m,\ storage\ aggregate\ media}$ = Media storage volume of storage aggregate media

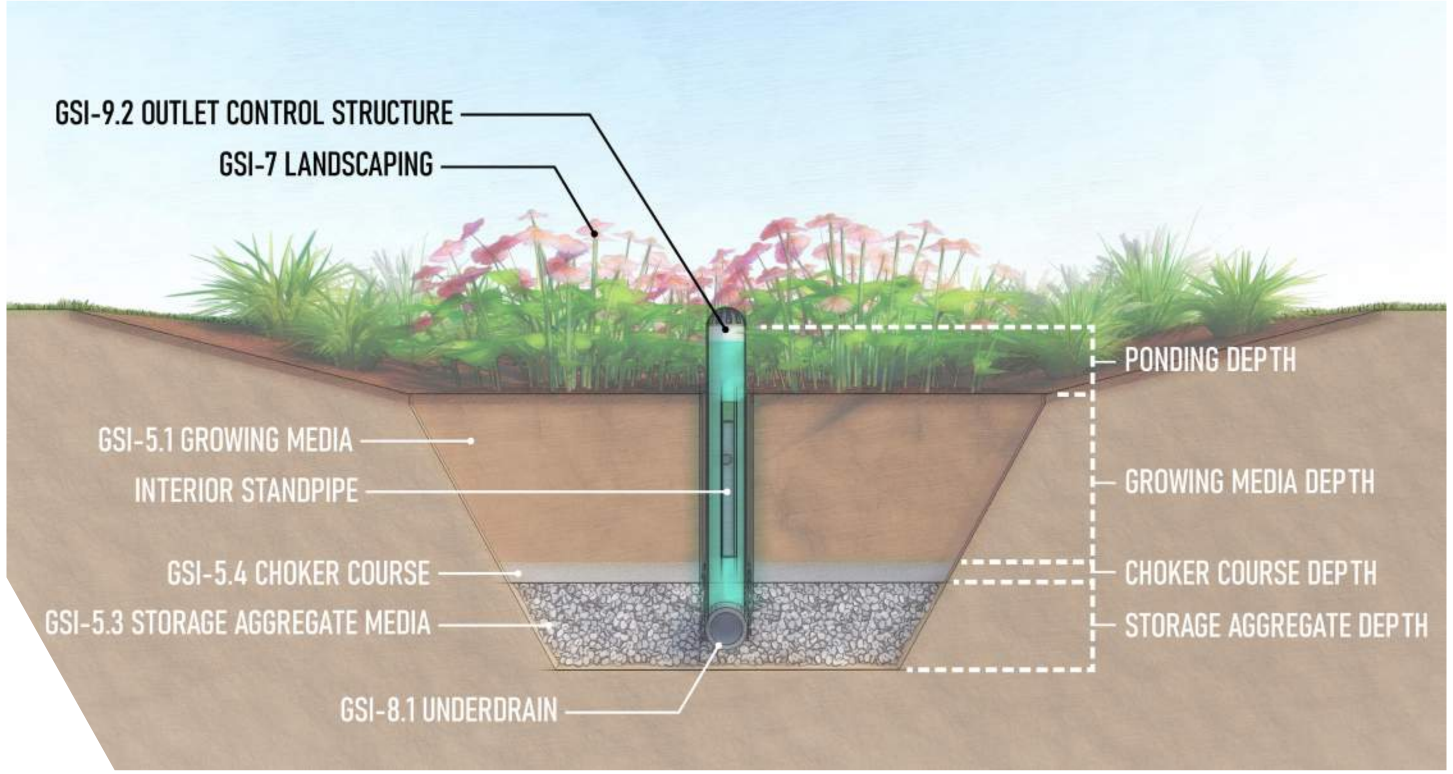
Equation 5605-7:

$$V_R = GSI_{RRF} * V_{GSI\ Storage}$$

V_R = Retention storage volume provided by retention practice (ft^3)

GSI_{RRF} = The GSI runoff reduction factor that represents the portion of the GSI storage volume that provides the credited retention benefits (%)

Figure 5605-2: Bioretention



Design Considerations

- Bioretention side slopes are recommended to be 4:1 (H:V) or shallower to mitigate erosion potential. Side slopes shall not exceed 3:1 (H:V).
- Designer must specify pre-construction infiltration testing per Specification Section 02956 to verify that in-situ subgrade saturated hydraulic conductivity reflects design assumptions.
- Designer must specify post-construction infiltration testing per Specification Section 02956 to verify that placed growing media infiltration rate is acceptable.
- Maximum ponding depth must be specified such that the maximum ponding depth can be dewatered within 48 hours after the rainfall event, based on the saturated hydraulic conductivity of the subgrade, unless an underdrain is utilized. The entire volume of water stored in the bioretention must be drawn down over 72 hours.
- Minimum ponding depth is 3 inches and maximum ponding depth is 18 inches. It is recommended that the ponding depth not exceed 12 inches.
- Bioretention is not a suitable GSI practice at locations where the water table is high or bedrock is present near the surface. A separation distance of 2 feet is required between the bottom of the excavated bioretention area and the seasonally high groundwater table or bedrock elevation.
- Bioretention facilities shall not be constructed within stream setbacks or in areas adjacent to streams where sediment may be deposited during frequent flood events.
- Provide maintenance access based on the equipment needed to maintain the facility and its components. Designer shall consider long-term maintenance responsibility and capacity when selecting GSI practice and components, as required per **Section 5609**.
- Bioretention can be designed to be off-line or on-line of the existing stormwater management system. Offline systems with designated routes around the bioretention basin for larger storm events is preferred.
  - Off-line systems: design flow for the 10-year design storm to safely bypass the bioretention area. Off-line systems do not require an overflow structure.
  - On-line systems: flow for the 10-year design storm shall not exceed 3 ft/s to avoid erosion of the growing media. Design the high flow overflow structure as a conventional stormwater control structure or channel. Connect the overflow structure to the site's stormwater conveyance system, or outfall to a suitable nonerosive location. On-line systems shall be designed with an **overflow spillway** to discharge flows that exceed the capacity of the overflow structure.

Typical GSI Components

At a minimum, bioretention practices include pretreatment, growing media, landscaping, and piping design components. Designers should also consider components required to route stormwater to, through, out, and/or around the bioretention during varying design storms. Below is a matrix showing the typical design components for bioretention. See **Section 5606** for additional information on each GSI Component.

Bioretention - GSI Component Matrix										
GSI-1	GSI-2	GSI-3	GSI-4	GSI-5	GSI-6	GSI-7	GSI-8	GSI-9	GSI-10	GSI-11
X	X	X		X	X	X	X	X		X

The following components should be considered when designing a bioretention practice. The list below provides general applicability and use considerations as it relates to the GSI Practice. Design considerations, design deliverable checklists, design detail templates, and reference to construction specifications, as applicable, for each component are included in the associated sections and should be referenced for detailed design.

GSI-1 Inlets (Optional), Section 5606.1

- Inlets may be used to collect and route stormwater into the bioretention. If stormwater enters the GSI via sheet flow, an inlet component may not be required.

GSI-2 Energy Dissipation & Pretreatment, Section 5606.2

- Energy dissipation and/or pollutant removal must be provided to reduce erosion within the bioretention and/or capture sediment, trash, and debris prior to entering the bioretention for consolidated maintenance activities.
- Energy dissipation is required for all bioretention applications including designs that collect stormwater via sheet flow due to the tendency of constructed grades to allow for concentrated flow points into the GSI.

GSI-3 Area Protection (Optional), Section 5606.3

- Area protection such as ribbon curbs or mow strips should be placed at the edge of the bioretention to delineate the extents of growing media and to differentiate the vegetation for maintenance purposes.
- Area protection must be used any time the change in grade between the bioretention and the directly adjacent surface exceeds 12 inches, when adjacent slopes exceed 3:1 (horizontal: vertical), or to meet site specific safety requirements. Area protection techniques that provide vertical visual barriers are most appropriate for these conditions, such as curbs (GSI-3.1), fencing and railing (GSI-3.2), or stone barriers (GSI-3.4).

GSI-5 Soil & Aggregate Media, Section 5606.5

- GSI-5.1 Growing Media: Designer must specify a growing media that meets the storage volume (porosity), infiltration, soil moisture, and nutrient needs of the bioretention.
- GSI-5.3 Storage Aggregate Media: Designer must specify a storage aggregate media that meets the storage volume (porosity) needs of the bioretention.
- GSI-5.4 Choker Course: Designer must specify a choker course between the growing media layer (GSI-5.1) and the storage aggregate media layer (GSI-5.3) such that the particle size of the choker course is less than the particle size of the storage aggregate media. Designer may include the choker course in the storage volume calculations, if applicable.

GSI-6 Media Liners (Optional), Section 5606.6

- GSI-6.1 Permeable Liner: Designer should specify permeable liner(s) if necessary for certain types of energy dissipation, vertical separation between GSI media and adjacent subgrade, and/or landscaping purposes. Permeable liners are generally not recommended on horizontal GSI media layers due to tendency for microbial blinding that limits or even prohibits infiltration into the subsurface.
- GSI-6.2 Impermeable Liner: If the GSI is adjacent to traditional pavement within the public right-of-way or a building, an impermeable liner shall be placed along the side of the GSI adjacent to the pavement or building. The impermeable liner shall extend a minimum depth below the GSI section such that the existing features are not within the infiltration zone of influence. The infiltration zone of influence is defined by the area within a 1:1 (H:V) slope line from the outer edge of the subsurface storage section.

GSI-7 Landscaping, Section 5606.7

- The role of plant species is to bind nutrients and other pollutants by plant uptake, to remove water through evapotranspiration, and to create pathways for infiltration through root development and plant growth. Root growth provides a media that fosters bacteriologic growth, which in turn develops a healthy soil structure.

- GSI-7.8 Existing Tree Protection: Designer must consider the impact to existing trees and root systems, specify protection measures for existing trees when possible, and incorporate tree replacements into the landscape plan when existing tree removal is necessary.
- GSI-7.10 Planting Plan: Designer must consider the location within the bioretention and anticipated inundation depths and durations when specifying vegetation. Sun and shade tolerance, soil moisture tolerances, acceptable plant material sizes at maturity, and aesthetic expectations must also be considered based on the finished conditions around the GSI.

GSI-8 Piping, Section 5606.8

- GSI-8.1 Underdrain: An underdrain is required unless infiltration testing results demonstrate that the entire bioretention can be drawn down within 72 hours. When an underdrain is necessary, designer shall use an adjustable flow control mechanism, such as a valve or upturned elbow on the underdrain, or a manufactured outlet control structure with inline weir (GSI-9.2) to maximize retention and/or **detention** capabilities and to provide adaptability to post-construction site conditions and performance. Connect the underdrain or overflow structure to the site's stormwater conveyance system, or outfall to a suitable nonerosive location.
- GSI-8.3 Cleanout: If an underdrain is included, designer must provide cleanouts or other accessible structures for maintenance access to the underdrain. At a minimum, cleanouts or other access structures must be included at the upstream and downstream end of the underdrain, at flow control mechanisms (if applicable), and at any transitions, fittings, or bends in the alignment.
- GSI-8.4: Observation Well: Designer must include an observation well to provide the owner with an access point to monitor the water level in the media volume and to understand the GSI performance. When an underdrain is included, cleanouts may also serve as observation wells.
- GSI-8.5 Anti-Seep Collar: If an underdrain is included, designer should consider an anti-seep collar to reduce preferential flow of stormwater from the underdrain pipe bedding and aggregate backfill to adjacent subgrade or adjacent underground utility corridors, especially in instances where an impermeable liner is also specified.

GSI-9 Outlets, Section 5606.9

- The water surface elevation above the outlet for the 10-year storm shall be determined, and at least 1" of freeboard above that elevation must be provided.
- GSI-9.1 Overflow Outlet: Designer must use an overflow outlet to control the ponding depth in the bioretention and allow for discharge of stormwater greater than the volume required for retention to the receiving system.
- GSI-9.2 Outlet Control Structure: If an underdrain is included, designer must configure outlet control structure(s) to control the discharge of stormwater to the receiving system, to maximize retention storage volumes, and to provide adaptability to post-construction site conditions and performance

GSI-11 Internal Control, Protection, & Stabilization, Section 5606.11

- Control, protection, and stabilization measures are required to safeguard the GSI practice and components against erosion and sedimentation from the contributing site during construction and into establishment.

B. Permeable Pavement System

Description:

Permeable pavement systems have a permeable surface (GSI-4) that allows stormwater to pass through to an underlaying aggregate layer that temporarily stores stormwater runoff. Permeable pavement systems capture stormwater runoff by collecting water through joints or pores in the surface, which consists of either pervious concrete, permeable pavers or porous asphalt. The water then moves through layers of aggregate below the permeable pavement surface before soaking into the ground or being dewatered through an underdrain. Typically, excess water is carried away through an underdrain and slowly released back to the receiving system.

GSI Storage & Sizing Calculations:

Permeable pavements provide stormwater storage in the choker course and storage aggregate media layer(s). Permeable pavement GSI storage is calculated as the total storage volume for each of its storage components, as follows:

Equation 5605-8:

$$V_{GSI\ Storage} = V_{m,\ choker\ course} + V_{m,\ storage\ aggregate\ media}$$

$V_{m,\ choker\ course}$ = Media storage volume of choker course

$V_{m,\ storage\ aggregate\ media}$ = Media storage volume of storage aggregate media

Equation 5605-9:

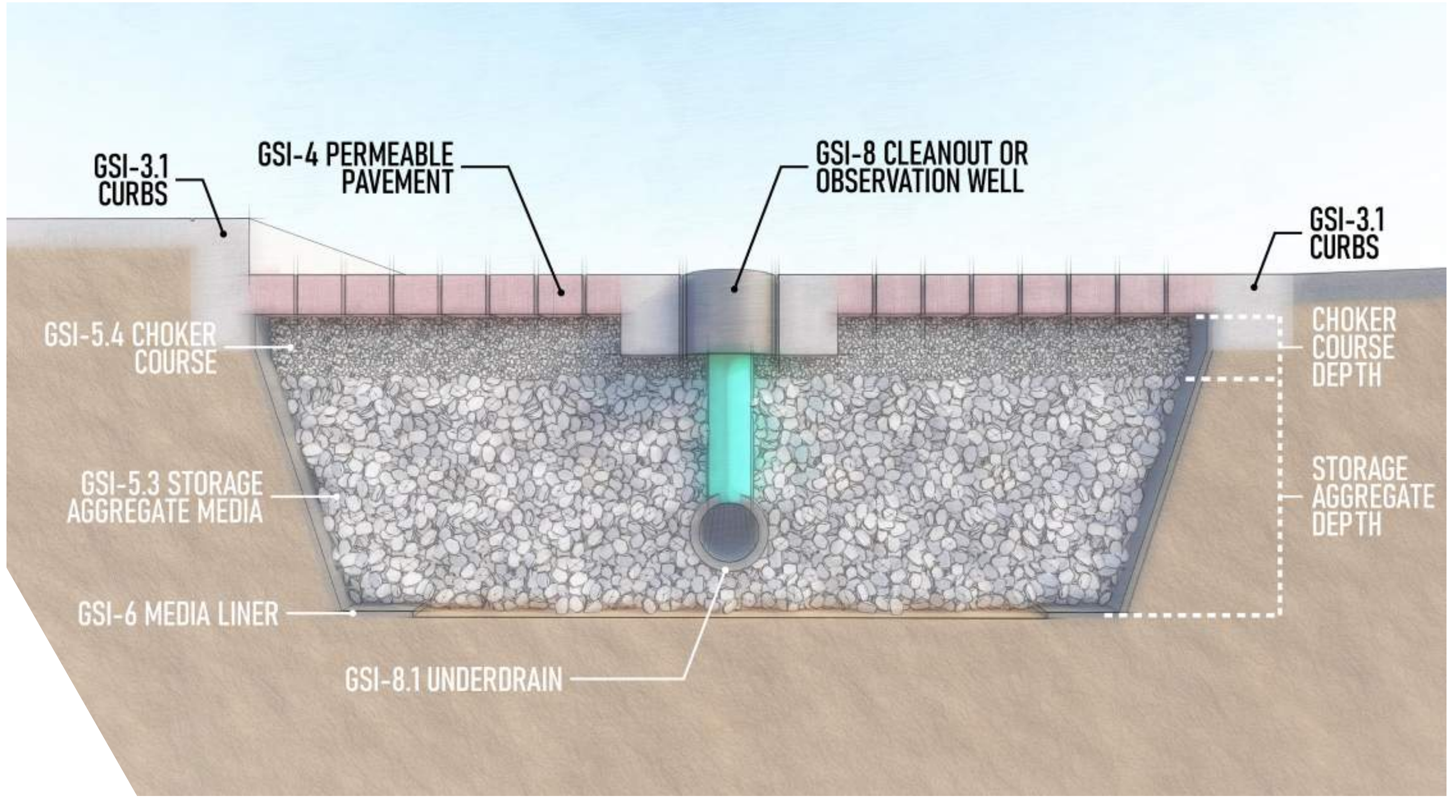
$$V_R = GSI_{RRF} * V_{GSI\ Storage}$$

V_R = Retention storage volume provided by retention practice (ft^3)

GSI_{RRF} = The GSI runoff reduction factor that represents the portion of the GSI storage volume that provides the credited retention benefits (%)

Additional storage aggregate media and/or storage chamber component layers may also be included if additional storage is needed. **GSI practices** that rely solely on infiltration into the surrounding soils should consider storage volume and storage depths necessary to meet desired drawdown times based on in-situ soil infiltration rates. See the **Section 5605.1 A**. Retention Design Calculations for volume and depth calculations for each individual storage layer.

Figure 5605-3: Permeable Pavement System



Design Considerations:

- Consider adjacent land use conditions and vegetative coverage when locating the facility. Tributary land use with high sediment loading or degrading pavements can clog downstream permeable pavement systems. Adjacent slopes without proper vegetative coverage may also be a source of sediment that could clog the permeable pavement system.
- Consider tree coverage when placing permeable pavement system adjacent to and/or beneath heavy tree canopy that deposits seeds, leaves, and other tree debris that may clog the permeable pavement.
- Consider the application of the permeable pavement system (detention and/or retention) when specifying compaction requirements for the subgrade. Limiting subgrade compaction is critical for retention systems that rely solely on infiltration for dewatering the subgrade.
- The entire volume of water stored in the permeable pavement must be drawn down over 48 hours.
- Consider the expected vehicle loading for the permeable pavement system. Depth of the permeable surface and aggregate layer must be sufficient to handle expected traffic volumes and vehicle loads.
- Designer must specify pre-construction infiltration testing per Specification Section 02956 to verify that in-situ subgrade saturated hydraulic conductivity reflects design assumptions.
- Designer must specify post-construction infiltration testing per Specification Section 02956 to verify that permeable pavement infiltration rate reflects design assumptions.
- Provide maintenance access based on the equipment needed to maintain the facility and its components. Designer shall consider long-term maintenance responsibility and capacity when selecting GSI practice and components, as required per **Section 5609**.
- Permeable pavement is not a suitable GSI practice at locations where the water table is high or bedrock is present near the surface. A separation distance of 2 feet is required between the bottom of the excavated permeable pavement area and the seasonally high groundwater table or bedrock elevation.
- Where additional areas are proposed to drain onto the permeable pavement, the maximum loading rate for contributing impervious drainage area to permeable pavement area is 3:1 or less (impervious tributary area : permeable pavement). If runoff is coming from adjacent pervious areas (such as grass lots), it is important that the pervious areas be fully stabilized to reduce sediment loads and prevent clogging of the permeable pavement system. Pretreatment using filter strips or vegetated swales for removal of coarse sediments is recommended and may reduce maintenance frequency.
- The maximum slope of permeable pavement is 10%. Slopes of 5% or less are recommended.

Typical GSI Components:

At a minimum, permeable pavement systems include permeable surface, aggregate media and piping design components. Designers should also consider components required to route stormwater through and out of the permeable pavement system to discharge stormwater greater than the retention capacity. Below is a matrix showing the typical design components that make up permeable pavement systems.

Permeable Pavement System - GSI Component Matrix										
GSI-1	GSI-2	GSI-3	GSI-4	GSI-5	GSI-6	GSI-7	GSI-8	GSI-9	GSI-10	GSI-11
		X	X	X	X	X	X	X	X	X

The following components should be considered when designing a permeable pavement practice. The list below provides general applicability and use considerations as it relates to the GSI Practice. Design considerations, design deliverable checklists, design detail templates, and reference to construction specifications, as applicable, for each component are included in the associated sections and should be referenced for detailed design.

GSI-3 Area Protection, Section 5606.3

- GSI 3.1 Curbs: Designer should use curbs to confine and/or delineate edges of permeable pavement when applicable. Curbs should be placed at the edges of flexible permeable pavements (such as porous asphalt and some permeable pavers) that do not abut rigid pavement; confining edges improve the strength and integrity of the flexible pavement. Designer should consult permeable paver manufacturer regarding installation and edging requirements.

GSI-4 Permeable Pavements, Section 5606.4

- Designer should consider the traffic conditions (loading, frequency of use, turn radius, etc.), desired surface infiltration rate, project aesthetics, and long-term maintenance when specifying the type of permeable pavement.

GSI-5 Soil & Aggregate Media, Section 5606.5

- GSI-5.3 Storage Aggregate Media: Designer must specify a storage aggregate media that meets the storage volume (porosity) needs of the permeable pavement system.
- GSI-5.4 Choker Course: Designer must specify a choker course between the permeable pavement (GSI-4) and the storage aggregate layer (GSI-5.3) such that the particle size of the choker course is less than the particle size of the storage aggregate media, depending on the type of permeable pavement specified. Designer may include the choker course in the storage calculations, if applicable. Some permeable paver products also include a jointing and bedding material for the paver surface. Designer should follow manufacturer's requirements for jointing and bedding material.

GSI-6 Media Liners (Optional), Section 5606.6

- GSI-6.1 Permeable Liner: Certain manufacturers of permeable pavement systems may require or recommend the use of a permeable liner or geogrid for stabilization; designer should specify the type and class of permeable liner that conforms to manufacturer requirements.
- GSI-6.2 Impermeable Liner: If the GSI is adjacent to traditional pavement within the public right-of-way or a building, an impermeable liner shall be placed along the side of the GSI adjacent to the pavement or building. The impermeable liner shall extend a minimum depth below the GSI section such that the existing features are not within the infiltration zone of influence. The infiltration zone of influence is defined by the area within a 1:1 (H:V) slope line from the outer edge of the subsurface storage section.

GSI-7 Landscaping (Optional), Section 5606.7

- GSI-7.8 Existing Tree Protection: Designer must consider the impact to existing trees and root systems, specify protection measures for existing trees when possible, and incorporate tree replacements into the landscape plan when existing tree removal is necessary.

GSI-8 Piping, Section 5606.8

- GSI-8.1 Underdrain: An underdrain is required unless infiltration testing results demonstrate that the entire permeable pavement system can be drawn down within 48 hours. When an underdrain is necessary, designer shall use an adjustable flow control mechanism, such as a valve or upturned elbow on the underdrain, or a manufactured outlet control structure with inline weir (GSI-9.2) to maximize retention and/or detention capabilities and to provide adaptability to post-construction site conditions and performance.
- GSI-8.3 Cleanout: If an underdrain is included, designer must provide cleanouts or other accessible structure for maintenance access to the underdrain. At a minimum cleanouts or other access structures must be included at the upstream and downstream end of the underdrain, at flow control mechanisms (if applicable), and at any transitions, fittings, or bends in the alignment.
- GSI-8.4: Observation Well: Designer must include an observation well to provide the owner with an access point to monitor the water level in the media volume and to understand the GSI performance. When an underdrain is included, cleanouts may also serve as observation wells.
- GSI-8.5 Anti-Seep Collar: If an underdrain is included, designer should consider an anti-seep collar to reduce preferential flow of stormwater from the underdrain pipe bedding and aggregate backfill to adjacent subgrade or adjacent underground utility corridors, especially in instances where an impermeable liner is also specified.

GSI-9 Outlets (Optional), Section 5606.9

- GSI-9.2 Outlet Control Structure: If an underdrain is included, designer must also configure outlet control structure(s) to control the discharge of stormwater to the receiving system, to maximize retention storage volumes, and to provide adaptability to post-construction site conditions and performance.

GSI-10 Storage Chambers (Optional), Section 5606.10

- Designer should consider the use of storage chambers to meet retention and/or detention requirements if additional GSI storage volume is needed and site space is limited. Storage chambers can provide greater volume per GSI footprint due to the larger void ratio of storage chambers compared to that of storage aggregate media.

GSI-11 Internal Control, Protection, & Stabilization, Section 5606.11

- Control, protection, and stabilization measures are required to safeguard the GSI practices and components against erosion and sedimentation from the contributing site during construction and into establishment.

C. Infiltration Trench

Description:

Infiltration trenches collect and store stormwater runoff in layers of aggregate media for infiltration into the adjacent subgrade. The surface aggregate used for infiltration trenches varies by application. Landscape applications typically incorporate a decorative gravel surface layer, while applications adjacent to pavement may use clean storage aggregate media. An underdrain may also be included to provide additional storage capacity or to drain excess stormwater, controlling the slow release of the collected stormwater back to the receiving system.

GSI Storage & Sizing Calculations:

Infiltration trenches provide stormwater storage in the void spaces of aggregate media layer(s). Infiltration trench GSI storage is calculated as the total storage volume for each of its storage components, as follows:

Equation 5605-10:

$$V_{GSI\ Storage} = V_{m,\ storage\ aggregate\ media}$$

$V_{m,\ storage\ aggregate\ media}$ = Media storage volume of storage aggregate media

Equation 5605-11:

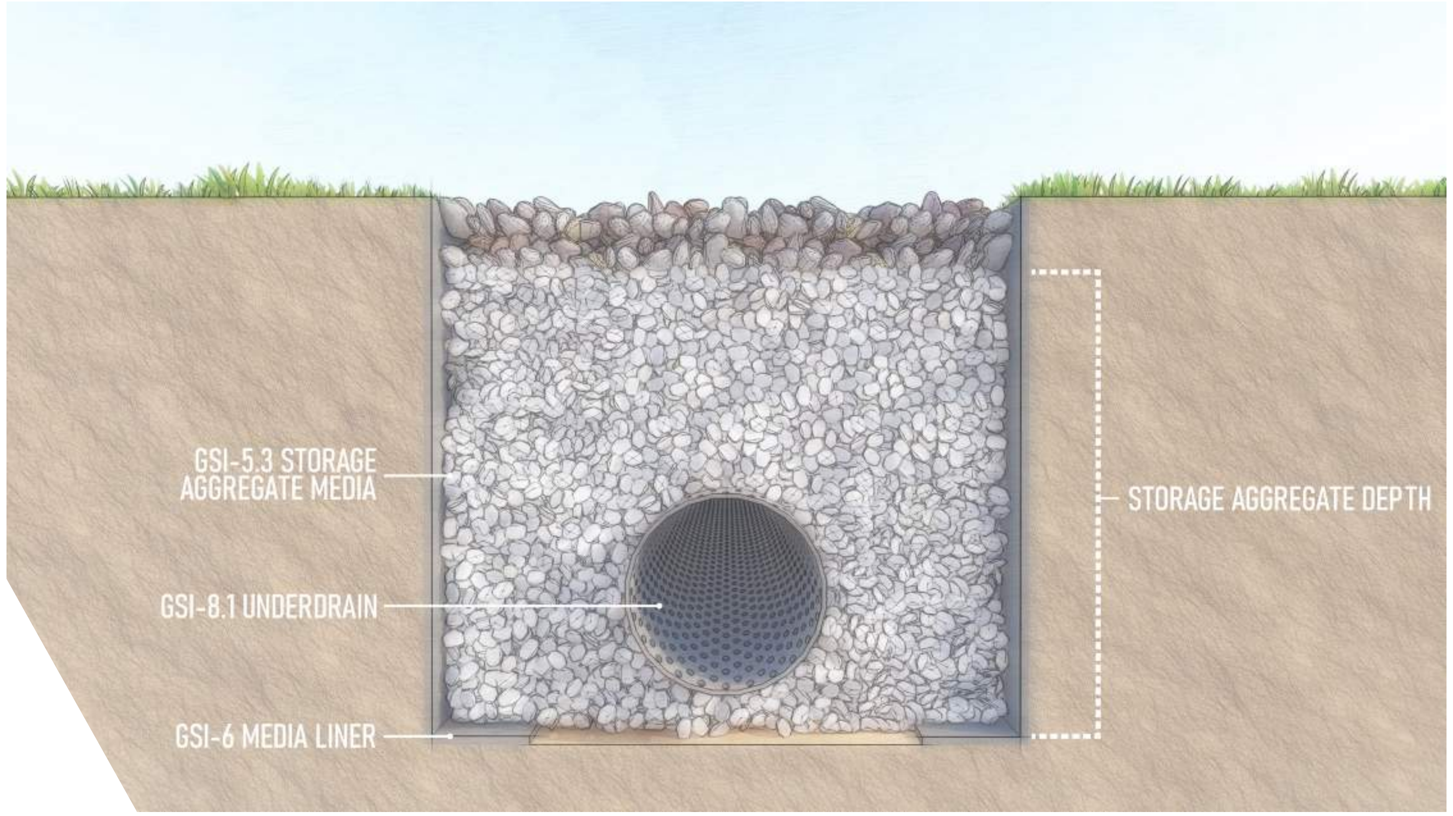
$$V_R = GSI_{RRF} * V_{GSI\ Storage}$$

V_R = Retention storage volume provided by retention practice (ft^3)

GSI_{RRF} = The GSI runoff reduction factor that represents the portion of the GSI storage volume that provides the credited retention benefits (%)

Additional storage aggregate media or storage chamber component layers may also be included if additional storage is needed. Infiltration trenches often rely solely on infiltration and should consider storage volume and media depths necessary to meet desired drawdown times based on in-situ infiltration rates. See the **Section 5605.1 A**. Retention Design Calculations for volume and depth calculations for each individual storage layer.

Figure 5605-4: Infiltration Trench



Design Considerations:

- Consider adjacent land use, conditions and vegetative coverage when selecting location of infiltration trench. Tributary land use with high sediment loading or degrading pavements can clog downstream infiltration trench. Adjacent slopes without proper vegetative coverage may also be a source of sediment that could clog the infiltration trench.
- Designer must specify pre-construction infiltration testing per Specification Section 02956 to verify that in-situ subgrade saturated hydraulic conductivity reflects design assumptions. Post- construction infiltration testing is not typically feasible due to high infiltration rates into the aggregate media.
- The entire volume of water stored in the infiltration trench must be drawn down over 72 hours.
- The maximum loading rate for contributing impervious drainage area to infiltration area is 5:1 and adjacent slopes must be 5% or less. If runoff is coming from adjacent pervious areas (such as grass lots), it is important that the pervious areas be fully stabilized to reduce sediment loads and prevent clogging of the infiltration system. Pretreatment using filter strips or vegetated swales for removal of coarse sediments is recommended and may reduce maintenance frequency.
- Infiltration trenches should have a depth between 3 and 8 feet. Design the volume of the trench to accommodate the **RRV** within the depth of the infiltration trench.
- Provide maintenance access based on the equipment needed to maintain the facility and its components.
- An infiltration trench is not a suitable **GSI practice** at locations where the water table is high or bedrock is present near the surface. A separation distance of 2 feet is required between the bottom of the excavated infiltration trench and the seasonally high groundwater table or bedrock elevation.
- If an infiltration trench will be exposed to vehicular traffic in any capacity, structural stability of the open graded aggregates must be considered. Use of a cellular confinement system may be needed if vehicular uses are anticipated.

Typical GSI Components:

At a minimum, infiltration trench practices include aggregate media, landscaping and piping design components. Designers should also consider components required to route stormwater to, through, out, and/or around the infiltration trench during varying design storms. Below is a matrix showing the typical design components that make up infiltration trenches.

Infiltration Trench - GSI Component Matrix										
GSI-1	GSI-2	GSI-3	GSI-4	GSI-5	GSI-6	GSI-7	GSI-8	GSI-9	GSI-10	GSI-11
X	X	X		X	X	X	X	X	X	X

The following components should be considered when designing an infiltration trench practice. The list below provides general applicability and use considerations as it relates to the GSI Practice. Design considerations, design deliverable checklists, design detail templates, and reference to construction specifications, as applicable, for each component are included in the associated sections and should be referenced for detailed design.

GSI-1 Inlets (Optional), Section 5606.1

- Inlets may be used to collect and route stormwater into an infiltration trench. If stormwater enters the GSI via sheet flow, an inlet component may not be required.

GSI-2 Energy Dissipation & Pretreatment (Optional), Section 5606.2

- Provide pretreatment to capture sediment, trash, and/or debris prior to entering the infiltration trench to minimize sediment buildup and clogging.

GSI-3 Area Protection (Optional), Section 5606.3

- Area protection may be placed at the edge of the infiltration trench to delineate the extents of trench and to provide a rigid barrier for the aggregate media.

GSI-5 Soil & Aggregate Media, Section 5606.5

- GSI-5.3 Storage Aggregate Media: Designer must specify a storage aggregate media that meets the storage volume (porosity) needs of the infiltration trench.
- GSI-5.4 Choker Course (Optional): Designer may specify a choker course between the surface aggregate and the storage aggregate media layer (GSI-5.3) such that the particle size of the choker course is less than the particle size of the storage aggregate media. If specified, designer may include the choker course in the storage volume calculations.

GSI-6 Media Liners (Optional), Section 5606.6

- GSI-6.1 Permeable Liner: If necessary for vertical separation between GSI media and adjacent subgrade, designer should specify permeable liner(s) on the sides of the infiltration trench. Permeable liners are generally not recommended on horizontal GSI media layers due to tendency for microbial blinding that limits or even prohibits infiltration into the subsurface.
- GSI-6.2 Impermeable Liner: If the GSI is adjacent to traditional pavement within the public right-of-way or a building, an impermeable liner shall be placed along the side of the GSI adjacent to the pavement or building. The impermeable liner shall extend a minimum depth below the GSI section such that the existing features are not within the infiltration zone of influence. The infiltration zone of influence is defined by the area within a 1:1 (H:V) slope line from the outer edge of the subsurface storage section.

GSI-7 Landscaping, Section 5606.7

- Decorative gravel may be used as the surface aggregate of the infiltration trench for aesthetic purposes.
- GSI-7.8 Existing Tree Protection: Designer must consider the impact to existing trees and root systems, specify protection measures for existing trees when possible, and incorporate tree replacements into the landscape plan when existing tree removal is necessary.

GSI-8 Piping, Section 5606.8

- GSI-8.1 Underdrain: An underdrain is required unless infiltration testing results demonstrate that the entire infiltration trench can be drawn down within 72 hours. When an underdrain is necessary, designer shall use an adjustable flow control mechanism, such as a valve or upturned elbow on the underdrain, or a manufactured outlet control structure with inline weir (GSI-9.2) to maximize retention and/or **detention** capabilities and to provide adaptability to post-construction site conditions and performance.
- GSI-8.3 Cleanout: If an underdrain is included, designer must provide cleanouts or other accessible structure for maintenance access to the underdrain. At a minimum cleanouts or other access structures must be included at the upstream and downstream end of the underdrain, at flow control mechanisms (if applicable), and at any transitions, fittings, or bends in the alignment.
- GSI-8.4 Observation Well: Designer must include an observation well to provide the owner with an access point to monitor the water level in the media volume and to understand the GSI performance. When an underdrain is included, cleanouts may also serve as observation wells.
- GSI-8.5 Anti-Seep Collar: If an underdrain is included, designer should consider an anti-seep collar to reduce preferential flow of stormwater from the underdrain pipe bedding and aggregate backfill to adjacent subgrade or adjacent underground utility corridors, especially in instances where an impermeable liner is also specified.

GSI-9 Outlets (Optional), Section 5606.9

- GSI-9.1 Overflow Outlet: Designer must use an overflow outlet to allow for discharge of stormwater greater than the volume required for retention within the infiltration trench to the receiving system. Because an infiltration trench does not have a ponding area, the overflow riser should be set at the finished surface elevation of the GSI Practice.
- GSI-9.2 Outlet Control Structure: If an underdrain is included, designer must also configure outlet control structure(s) to control the discharge of stormwater to the receiving system, to maximize retention storage volumes, and to provide adaptability to post-construction site conditions and performance.

GSI-10 Storage Chambers (Optional), Section 5606.10

- Designer may consider the use of storage chambers to meet retention and/or detention requirements if additional GSI storage volume is needed and site space is limited. Storage chambers can provide greater volume per GSI footprint due to the larger porosity or open space within the storage chambers compared to that of storage aggregate media.

GSI-11 Internal Control, Protection, & Stabilization, Section 5606.11

- Control, protection, and stabilization measures are required to safeguard the GSI practices and components against erosion and sedimentation from the contributing site during construction and into establishment.

D. Wetland

Description:

Wetlands are constructed basins with variable depth pools and native vegetation zones designed to temporarily store stormwater after a rain event before slowly releasing it back to the receiving system. These are constructed wetlands, not natural wetlands and should be differentiated as such. Wetlands have a shallow permanent pool of water in dry-weather conditions and provide temporary detention above the permanent pool. Wetlands utilize settlement of total suspended solids as well as biological uptake of nutrients and dissolved solids for water quality enhancement. Wetlands vary from wet detention basins primarily by having a shallower permanent pool depth and corresponding larger surface area, as well as having designated wet and dry zones that support a range of vegetative landscaping and promote a diverse ecological habitat.

GSI Storage & Sizing Calculations:

Wetland GSI storage is the storage provided in the permanent pool below the primary outlet control structure, including the various micropools, low marsh zones, and high marsh zones.

Wetlands can also provide peak flow reduction for larger design storms to meet detention requirements. Detention storage is provided above the permanent pool volume, with an outlet structure designed to meet **required release rates**. For this reason, it is recommended that wetland sizing and storage be determined using a dynamic stormwater model with multi-year simulations representing dry and wet periods. The wetland storage should be sized to optimize stormwater retention requirements for the **required retention volume** (RRV) as well as the peak flow rate requirements for larger storm events, as applicable. Wetland storage and sizing should also consider water budget calculations to maintain a permanent wet pool.

If **continuous monitoring and adaptive controls (CMAC)** technology is used to optimize storage and function of the **GSI practice**, the CMAC-controlled volume between the permanent pool and the secondary outlet control structure may be factored into the storage volume provided by the retention practice.

Equation 5605-12:

$$GSI_{Storage} = V_P$$

V_P = Open storage volume provided in the permanent pool below the primary outlet control structure elevation (ft^3)

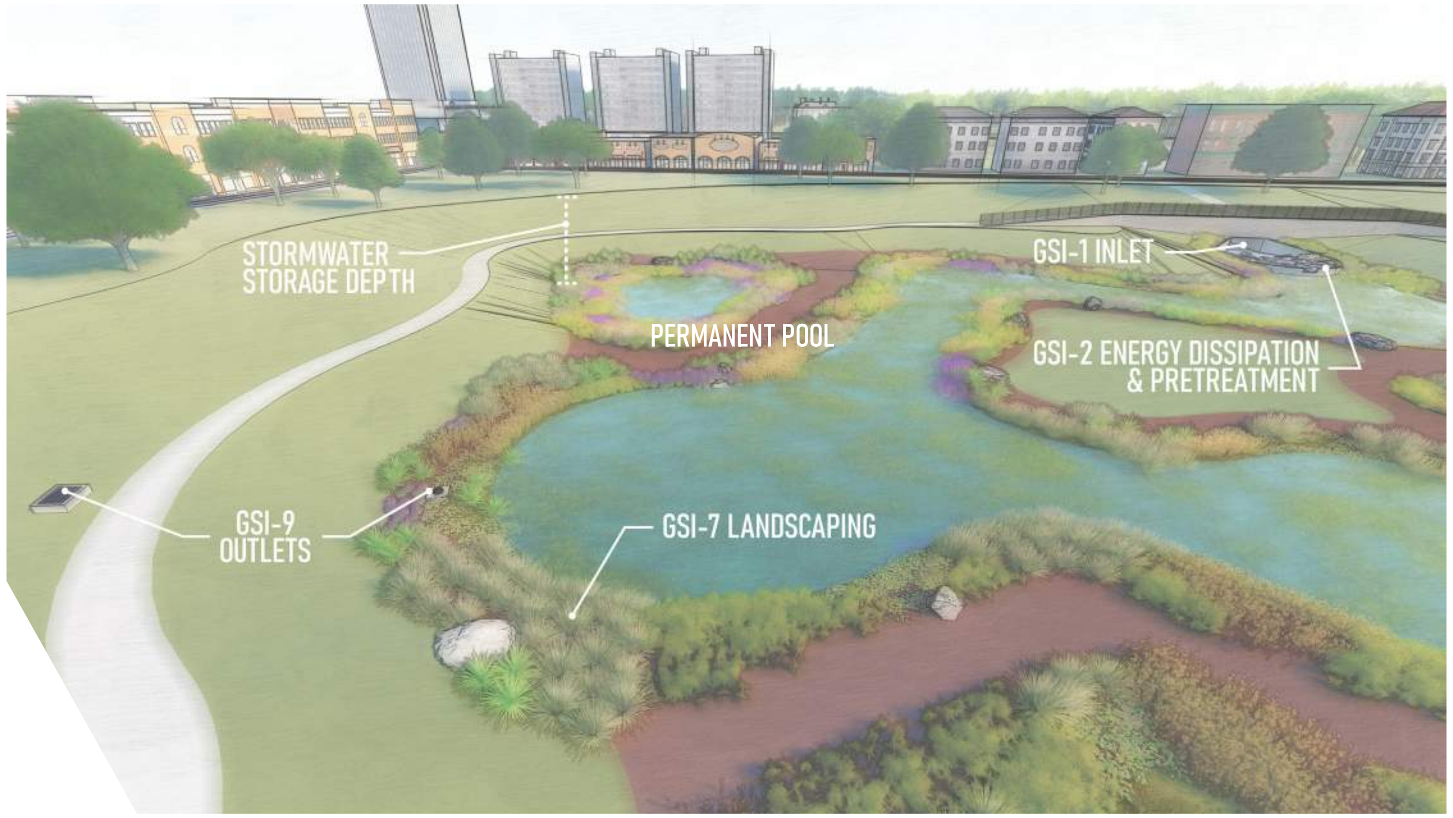
Equation 5605-13:

$$V_R = GSI_{RRF} * V_{GSI\ Storage}$$

V_R = Retention storage volume provided by retention practice (ft^3)

GSI_{RRF} = The GSI runoff reduction factor that represents the portion of the GSI storage volume that provides the credited retention benefits (%)

Figure 5605-5: Wetland



Design Considerations:

- The maximum temporary ponding depth of the storage above the permanent pool elevation must be limited to 4 feet and must be specified such that this storage volume can be dewatered within 72 hours after the end of the rainfall event, based on the outlet configuration. If wetland is used to meet retention requirements, the 2-year storm must be drawn down over 24-72 hours.
- Designer must calculate a water budget to verify that a permanent pool and wetland vegetation can be sustained. This may be done through use of a dynamic stormwater model with multi-year simulations, or through the following calculations representing a 3-month dry period. The calculated total loss is equal to the minimum main pool depth.

Equation 5605-14:

$$V_{in} = \frac{3\ in}{12}[0.00N + 0.95I + 0.25P + Rv_X X]$$

V_{in} = Total runoff entering the wetland over a 3-month dry period with 3 inches of rainfall (ft^3)
3 = 3 inches of rainfall
12 = Feet to inches conversion
0.00 = Runoff coefficient for preserved or restored natural area
N = Natural area of preservation or restoration within the wetland drainage area (ft^2).
0.95 = Runoff coefficient for impervious area
I = Impervious area within the wetland drainage area (ft^2)
0.25 = Runoff coefficient for pervious area
P = Pervious area within the wetland drainage area, not including any Natural Areas (ft^2)
Rv_X = Runoff coefficient for other unique land cover types, (**Table 5602-3**)
X = Area of other type within the wetland drainage area (ft^2)

Equation 5605-15:

$$Total\ loss_{\ (inches)} = Evaporation\ Depth - \left(\frac{V_{in}}{Pool\ Area} * 12\right)$$

Evaporation Depth = Evaporation over a 3-month dry period (approximately 30 inches should be assumed for the MARC region)
V_{in} = Total runoff entering the wetland over a 3-month dry period with 3 inches of rainfall (ft^3)
Pool Area = Area of permanent pool of water (ft^2)
12 = Feet to inches conversion

- ➔ Wetland grading must include varying depth zones within the permanent pool, including deeper micropools, low marsh areas, and high marsh areas with the following depth, grading, and side slope requirements:
  - » Permanent pool: main pool depth must exceed the total loss calculated by the water budget and generally be designed for a depth of 18-36 inches to ensure sufficient water depth during drought conditions. Side slopes below the permanent pool shall be 3:1 (H:V) or shallower. Side slopes above the permanent pool are recommended to be 4:1 (H:V) or flatter to mitigate erosion potential.
  - » Forebay: 4 to 6 feet deep near inlet to the wetland to provide energy dissipation and pretreatment (GSI-2). Forebay should be sized to store approximately 10% of the **water quality storm**.
  - » Micropool: 4 to 6 feet deep near the outlet to prevent clogging.
  - » Low marsh zone(s): 6-36 inches deep. The low marsh zone should make up approximately 25% of the wetland surface area.
  - » High marsh zone(s): < 6 inches deep. The high marsh zone should make up approximately 70% of the wetland surface area.
  - » Incorporating cascades into the wetland grading can provide aeration and increase oxygen levels to improve water quality benefits
  - » Safety Bench: Include a minimum 10-foot-wide safety bench around all forebays and micropools. Safety bench shall have a slope of 6:1 (H:V) or flatter and be either a part of the high marsh zone or above the permanent pool elevation. If safety bench slopes exceed 6:1 or are not feasible, then fencing is required per GSI-3.2 (**Section 5606.3**).
  - » Designer should consider micro-drainage to facility side slopes and permanently reinforce landscape areas likely to receive concentrated flow from adjacent or nearby pavement areas.
  - » Overflow spillway shall include permanent stabilization measures capable of withstanding anticipated flows for the 100-year design storm.
- ➔ If embankment meets the local, state or federal definition for a "dam," then design of dam shall adhere to all local, state, or federal requirements.
- ➔ Designer should site the outlet as far from inlet point(s) into the wetland as possible to prevent collected stormwater from short-circuiting the facility. Where the inlet and outlet must be located near each other, a berm or peninsula shall be incorporated to extend the flowpath through the wetland.
- ➔ If design relies on in-situ soil to maintain the permanent pool, designer must specify pre- construction infiltration testing per Specification Section 02956 to verify that in-situ subgrade saturated hydraulic conductivity is low enough to maintain the wet feature. If infiltration results are higher than anticipated, designer must specify an impermeable liner to maintain the permanent pool.

Figure 5605-6: Wetland Section

- ➔ Designer must specify post-construction infiltration testing per Specification Section 02956 to verify that soil hydraulic conductivity reflects design assumptions after final grading is completed such that the basin can maintain the permanent pool.
- ➔ Provide maintenance access based on the equipment needed to maintain the facility and its components. Designer shall consider long-term maintenance responsibility and capacity when selecting GSI practice and components, as required per Section 5609. Designer must include a maintenance ramp and perimeter access path. Design must also include a separate drain pipe with valve capable of completely dewatering the wetland for maintenance purposes.

Typical GSI Components:

At a minimum, wetland practices include inlets, pretreatment, area protection, growing media, landscaping, piping, and outlet design components. Designers should also consider components required to route stormwater to, through, and out the wetland during seasonal variations. Below is a matrix showing the typical design components that make up wetlands.

Wetland - GSI Component Matrix

GSI-1	GSI-2	GSI-3	GSI-4	GSI-5	GSI-6	GSI-7	GSI-8	GSI-9	GSI-10	GSI-11
X	X	X		X	X	X	X	X		X

The following components should be considered when designing a wetland practice. The list below provides general applicability and use considerations as it relates to the GSI Practice. Design considerations, design deliverable checklists, design detail templates, and reference to construction specifications, as applicable, for each component are included in the associated sections and should be referenced for detailed design.

GSI-1 Inlets, Section 5606.1

- ➔ Inlets may be used to collect and route stormwater into the wetland. Inlets may collect stormwater upstream of the basin and route stormwater to the GSI via piping components (GSI-8).

GSI-2 Energy Dissipation & Pretreatment, Section 5606.2

- ➔ Energy dissipation must be provided at inflow point(s) to the wetland to prevent scour and reduce sediment resuspension.
- ➔ Wetland must incorporate a sediment forebay for pretreatment to capture sediment, trash, and debris prior to entering the wetland and for consolidated maintenance activities.
  - » The sediment forebay must be separated from the wetland by a berm, weir, or wall structure.
  - » To make sediment removal easier, the bottom and side slopes of the forebay may be lined with concrete, tied-concrete-block mats or similarly stable material.

GSI-3 Area Protection (Optional), Section 5606.3

- ➔ Area protection may be used to signal a difference in vegetation for maintenance purposes.
- ➔ Area protection must be used any time there is a significant change in grade or elevation between the wetland and the surrounding area, to limit access to the GSI, or for safety purposes, as needed.

GSI-6 Media Liners (Optional), Section 5606.6

- ➔ GSI-6.1 Permeable Liner: Designer should specify permeable liner(s) if necessary for certain types of energy dissipation and/or landscaping purposes.
- ➔ GSI-6.2 Impermeable Liner: An impermeable liner may be required to maintain a permanent pool if desired permeability cannot be achieved with native site soils.

GSI-7 Landscaping, Section 5606.7

- ➔ The role of plant species is to bind nutrients and other pollutants by plant uptake, to remove water through evapotranspiration, and to create pathways for infiltration through root development and plant growth. Root growth provides a media that fosters bacteriologic growth, which in turn develops a healthy soil structure.
- ➔ GSI-7.8 Existing Tree Protection: Designer must consider the impact to existing trees and root systems, specify protection measures for existing trees when possible, and incorporate tree replacements into the landscape plan when existing tree removal is necessary.
- ➔ GSI-7.10 Planting Plan: Designer must consider the location within the wetland, anticipated inundation depths and durations when specifying vegetation. Sun and shade tolerance, soil moisture tolerances, acceptable plant material sizes at maturity, and aesthetic expectations must be considered based on the finished conditions around the GSI. Designer must specify wetland species suited to designed water depths for the low and high marsh zones and consider stress tolerance and hardiness to seasonal variation in water availability.

GSI-8 Piping, Section 5606.8

- Provide piping from the inlets (GSI-1) to the wetland.
- GSI-8.1 Underdrain: A minimum 8-inch diameter drain pipe with valve must be included to allow for dewatering of the basin for maintenance purposes. Consider anchoring needs to prevent flotation.
- GSI-8.3 Cleanout: Designer must provide cleanouts for maintenance access to the underdrain. At a minimum cleanouts or other access structures should be included at the upstream and downstream end of the underdrain, and at any transitions, fittings, or bends in the alignment.
- GSI-8.5 Anti-Seep Collar: Anti-seep collars must be specified for all pipes through material subject to saturation and seepage within earthen embankments.

GSI-9 Outlets, Section 5606.9

- GSI-9.1 Overflow Outlet: Designer may use an overflow outlet to control the ponding depth above the permanent pool in the wet detention basin and/or to allow for discharge of stormwater greater than the design event to the receiving system.
- GSI-9.2 Outlet Control Structure: Designer must specify an outlet control structure capable of maintaining the required drawdown time and release rates for the various design storms.
  - **Primary control structure**: shall be designed to control the 2-year design storm if wetland is utilized to meet detention requirements. If the wetland is utilized to meet retention requirements, the primary control structure must draw down the 2-year storm over 24-72 hours.
  - **Secondary control structure**: shall be designed to control the 10-year and up to the 100-year design storms if wetland is utilized to meet detention requirements
  - **Overflow spillway**: shall be sized to safely pass rainfall events larger than the design capacity of the wetland. If wetland is utilized to meet detention requirements, overflow spillway shall be designed to control the 100-year design storm.
- Outlet structures shall be protected by trash racks, well screens, grates, stone filters, submerged inlet pipes to the outflow structure, or other approved devices to minimize clogging potential and frequency of structure.
- Outlet structures shall have a minimum opening size of 1". If the required release rate results in an opening size < 4", the opening must be protected by a submerged inlet pipe with stone filter or set in a weir control structure within the outlet control structure. If the required release rate results in an opening size <1", the maximum allowable release shall be equal to the release rate achieved with a 1" opening.

GSI-11 Internal Control, Protection, & Stabilization, Section 5606.11

- Control, protection, and stabilization measures are required to safeguard the GSI practices and components against erosion and sedimentation from the contributing site during construction and into establishment.

E. Wet Detention Basin

Description:

Wet detention basins are stormwater ponds that temporarily store stormwater after a rain event before slowly releasing it back to the receiving system. These basins have a permanent pool of water in dry weather conditions and provide a temporary **detention** volume above the permanent pool during wet weather conditions. Wet detention basins primarily utilize settling of particles and associated pollutants for water quality enhancement when they capture and detain stormwater. Wet detention basins also provide water quality enhancement through uptake of nutrients via biological and chemical activity in the ponded storage.

GSI Storage & Sizing Calculations:

Wet detention basin GSI storage is the storage provided in the permanent pool below the primary outlet control structure.

Wet detention basins can also provide peak flow reduction for larger design storms to meet detention requirements. Detention storage is provided above the permanent pool volume, with an outlet structure designed to meet **required release rates**. For this reason, it is recommended that wet detention basin sizing and storage be determined using a dynamic stormwater model. The wet detention basin storage should be sized to optimize stormwater detention requirements for the target capture volume as well as the peak flow rate requirements for larger storm events, as applicable. Wet detention storage and sizing should also **consider water budget calculations** to maintain a permanent wet pool.

If **continuous monitoring and adaptive controls (CMAC)** technology is used to optimize storage and function of the **GSI practice**, the CMAC-controlled volume between the permanent pool and the secondary outlet control structure may be factored into the storage volume provided by the retention practice.

Equation 5605-16:

$$GSI_{Storage} = V_P$$

V_P = Open storage volume provided in the permanent pool below the primary outlet control structure elevation (ft^3)

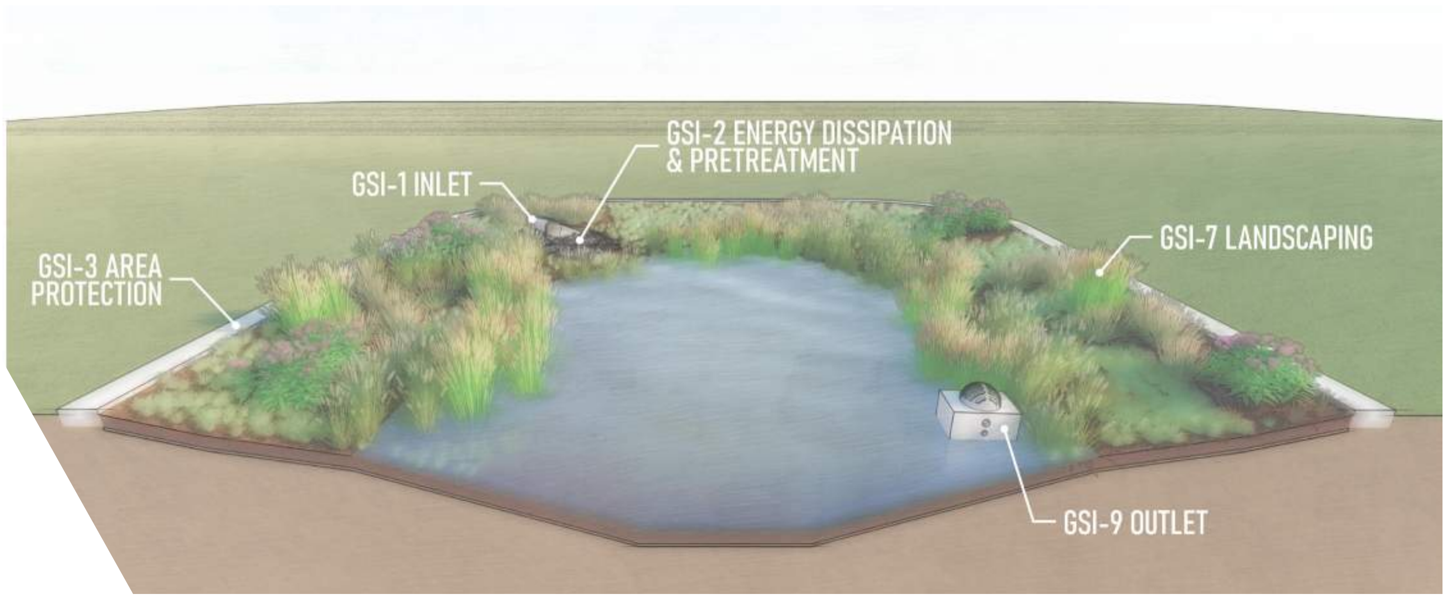
Equation 5605-17:

$$V_R = GSI_{RRF} * V_{GSI\ Storage}$$

V_R = Retention storage volume provided by retention practice (ft^3)

GSI_{RRF} = The GSI runoff reduction factor that represents the portion of the GSI storage volume that provides the credited retention benefits (%)

Figure 5605-7: Wet Detention Basin



Design Considerations:

- The maximum temporary ponding depth of the storage above the permanent pool elevation shall be specified such that this storage volume can be dewatered within 72 hours after the end of the rainfall event, based on the outlet configuration. If wet detention basin is used to meet retention requirements, the 2-year storm must be drawn down over 24-72 hours.
- Designer must calculate a water budget to verify that a permanent pool can be sustained. This may be done through use of a dynamic stormwater model with multi-year simulations, or through the following calculations representing a 3-month dry period. The calculated total loss is equal to the minimum main pool depth.

Equation 5605-18:

$$V_{in} = \frac{3\ in}{12}\left[0.00N + 0.95I + 0.25P + Rv_X X\right]$$

V_{in} =	Total runoff entering the wetland over a 3-month dry period with 3 inches of rainfall (ft^3)
3 =	3 inches of rainfall
12 =	Feet to inches conversion
0.00 =	Runoff coefficient for preserved or restored natural area
N =	Natural area of preservation or restoration within the wet detention basin drainage are (ft^2).
0.95 =	Runoff coefficient for impervious area
I =	Impervious area within the wet detention basin drainage area (ft^2)
0.25 =	Runoff coefficient for pervious area
P =	Pervious area within the wet detention basin drainage area, not including any Natural Areas (ft^2)
Rv_X =	Runoff coefficient for other unique land cover types, (**Table 5602-3**)
X =	Are of other type within the wet detention basin drainage area (ft^2)

Equation 5605-19:

$$Total\ loss_{(inches)} = Evaporation\ Depth - \left(\frac{V_{in}}{Pool\ Area} * 12\right)$$

Evaporation Depth =	Evaporation over a 3-month dry period (approximately 30 inches can be assumed for the MARC region)
V_{in} =	Total runoff entering the wetland over a 3-month dry period with 3 inches of rainfall (ft^3)
Pool Area =	Area of permanent pool of water (ft^2)
12 =	Feet to inches conversion

- Designer must consider the following grading, benching and side slope requirements:
  - Permanent pool: main pool depth must exceed the total loss calculated by the water budget. Side slopes shall be 3:1 (H:V) or shallower.
  - Forebay: 4 to 6 feet deep near inlet to the wet pond to provide energy dissipation and pretreatment (GSI-2). Forebay should be sized to store approximately 10% of the **water quality storm**.
  - Littoral Bench: a planting surface for aquatic vegetation shall extend inward at least 10 feet from the perimeter of the permanent pool and shall be between 6-12 inches below the permanent pool surface with slope of 6:1 (H:V) or shallower. Side slopes above the littoral bench are recommended to be 4:1 (H:V) or shallower to mitigate erosion potential.
  - Designer should consider micro-drainage to facility side slopes and permanently reinforce landscape areas likely to receive concentrated flow from adjacent or nearby pavement areas.
  - Overflow spillway shall include permanent stabilization measures capable of withstanding anticipated flows for the 100-year design storm.
- If embankment meets the local, state or federal definition for a “dam,” then design of dam shall adhere to all local, state, or federal requirements.
- Designer should site the outlet as far from inlet point(s) into the wet detention basin as possible to prevent collected stormwater from short-circuiting the facility. Where the inlet and outlet must be located near each other, a berm or peninsula shall be incorporated to extend the flowpath through the wet pond.
- If design relies on in-situ soil to maintain the permanent pool, designer must specify pre- construction infiltration testing per Specification Section 02956 to verify that in-situ subgrade saturated hydraulic conductivity is low enough to maintain the wet feature. If infiltration results are higher than anticipated, designer must specify an impermeable liner to maintain the permanent pool.
- Designer must specify post-construction infiltration testing per Specification Section 02956 to verify that soil hydraulic conductivity reflects design assumptions after final grading is completed such that the basin can maintain the permanent pool.
- Provide maintenance access based on the equipment needed to maintain the facility and its components. Designer shall consider long-term maintenance responsibility and capacity when selecting GSI practice and components, as required per Section 5609. Designer must include a maintenance ramp and perimeter access path. Design must also include a separate drain pipe with valve capable of completely dewatering the wetland for maintenance purposes.

Typical GSI Components:

At a minimum, wet detention basin practices include inlet, pretreatment, area protection, growing media, landscaping, piping and outlet design components. Designers should also consider components required to route stormwater to, through, and out the wet detention basin during varying design storms. Below is a matrix showing the typical design components that make up wet detention basins.

Wet Detention Basin - GSI Component Matrix										
GSI-1	GSI-2	GSI-3	GSI-4	GSI-5	GSI-6	GSI-7	GSI-8	GSI-9	GSI-10	GSI-11
X	X	X			X	X	X	X		X

The following components should be considered when designing a wet detention practice. The list below provides general applicability and use considerations as it relates to the GSI Practice. Design considerations, design deliverable checklists, design detail templates, and reference to construction specifications, as applicable, for each component are included in the associated sections and should be referenced for detailed design.

GSI-1 Inlets, Section 5606.1

- Inlets may be used to collect and route stormwater into a wet detention basin. Inlets may collect stormwater upstream of the basin and route stormwater to the GSI via piping components (GSI-8).

GSI-2 Energy Dissipation & Pretreatment, Section 5606.2

- Energy dissipation must be provided at inflow point(s) to the wet detention basin to prevent scour and reduce sediment resuspension.
- Wet detention basin must incorporate a sediment forebay for pretreatment to capture sediment, trash, and debris prior to entering the wetland and for consolidated maintenance activities.
    - The sediment forebay must be separated from the permanent pool by a berm, weir, or wall structure.
    - To make sediment removal easier, the bottom and side slopes of the forebay may be lined with concrete, tied-concrete-block mats or similarly stable material.

GSI-3 Area Protection (Optional), Section 5606.3

- Area protection may be placed at the edge of the wet detention basin to signal a difference in vegetation for maintenance purposes.
- Area protection must be used any time there is a significant change in grade or elevation between the wet detention basin and the surrounding area, to limit access to the GSI, or for safety purposes, as needed.

GSI-6 Media Liners (Optional), Section 5606.6

- GSI-6.1 Permeable Liner: Designer should specify permeable liner(s) if necessary for certain types of energy dissipation and/or landscaping purposes.
- GSI-6.2 Impermeable Liner: An impermeable liner may be required to maintain a permanent pool if desired permeability cannot be achieved with native site soils.

GSI-7 Landscaping, Section 5606.7

- The role of plant species is to bind nutrients and other pollutants by plant uptake, to remove water through evapotranspiration, and to create pathways for infiltration through root development and plant growth. Root growth provides a media that fosters bacteriologic growth, which in turn develops a healthy soil structure.
- GSI-7.8 Existing Tree Protection: Designer must consider the impact to existing trees and root systems, specify protection measures for existing trees when possible, and incorporate tree replacements into the landscape plan when existing tree removal is necessary.
- GSI-7.10 Planting Plan: Designer must consider the location within the wet detention basin and anticipated inundation depths and durations when specifying vegetation soil moisture tolerances. Sun and shade tolerance, acceptable plant material sizes at maturity, and aesthetic expectations must also be considered based on the finished conditions around the GSI. Designer must specify inundation tolerant native vegetation in the littoral zone; and drought and inundation tolerant native vegetation above the littoral zone.

GSI-8 Piping, Section 5606.8

- Provide piping from the inlets (GSI-1) to the wet detention basin.
- GSI-8.1 Underdrain: A minimum 8-inch diameter drain pipe with valve must be included to allow for dewatering of the basin for maintenance purposes.
- GSI-8.3 Cleanout: Designer must provide cleanouts for maintenance access to the underdrain. At a minimum cleanouts or other access structures should be included at the upstream and downstream end of the underdrain, and at any transitions, fittings, or bends in the alignment.
- GSI-8.5 Anti-Seep Collar: Anti-seep collars must be specified for all pipes through material subject to saturation and seepage within earthen embankments.

GSI-9 Outlets, Section 5606.9

- GSI-9.1 Overflow Outlet: Designer may use an overflow outlet to control the ponding depth above the permanent pool in the wet detention basin and/or to allow for discharge of stormwater greater than the design event to the receiving system.
- GSI-9.2 Outlet Control Structure: Designer must specify an outlet control structure capable of maintaining the required drawdown time and release rates for the various design storms.
    - **Primary control structure**: shall be designed to control the 2-year design storm if the wet detention basin is utilized to meet detention requirements. If the wet detention basin is utilized to meet retention requirements, the primary control structure must draw down the 2-year storm over 24-72 hours.
    - **Secondary control structure**: shall be designed to control the 10-year and up to the 100-year design storms if the wet detention basin is utilized to meet detention requirements
    - **Overflow spillway**: shall be sized to safely pass rainfall events larger than the design capacity of the wetland. If the wet detention basin is utilized to meet detention requirements, overflow spillway shall be designed to control the 100-year design storm.
- Outlet structures shall be protected by trash racks, well screens, grates, stone filters, submerged inlet pipes to the outflow structure, or other approved devices to minimize clogging potential and frequency of structure.
- Outlet structures shall have a minimum opening size of 1". If the required release rate results in an opening size < 4", the opening must be protected by a submerged inlet pipe with stone filter or set in a weir control structure within the outlet control structure. If the required release rate results in an opening size <1", the maximum allowable release shall be equal to the release rate achieved with a 1" opening.

GSI-11 Internal Control, Protection, & Stabilization, Section 5606.11

- Control, protection, and stabilization measures are required to safeguard the GSI practices and components against erosion and sedimentation from the contributing site during construction and into establishment.

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F. Dry Detention Basin

Description:

Dry detention basins are excavated areas that temporarily store stormwater after a rain event before slowly releasing it back to the receiving system. These basins are empty under dry-weather conditions and do not maintain a permanent pool, although they may include retention storage below the primary outlet structure that facilitates infiltration. Dry detention basins are primarily used to reduce peak runoff rates during storm events.

GSI Storage & Sizing Calculations:

Dry detention basin GSI storage is equal to the volume held below the **primary outlet structure**. This volume of water must be able to infiltrate within 72 hours, according to Equation 3 defined in **Section 5605.1 A**, or dewatered through an underdrain.

Dry detention basins can also provide peak flow reduction for larger design storms with an outlet structure designed to meet required release rates. For this reason, it is recommended that detention basin sizing and storage be determined using a dynamic stormwater model. The detention storage should be sized to optimize stormwater detention requirements for the required retention volume (RRV) as well as the peak flow rate requirements for larger storm events, as applicable.

If **continuous monitoring and adaptive controls (CMAC)** technology is used to optimize storage and function of the **GSI practice**, the CMAC-controlled volume between the primary and the secondary outlet control structure may be factored into the storage volume provided by the retention practice.

Equation 5605-20:

$$GSI_{Storage} = V_P$$

V_P = Open storage volume provided below the primary outlet control structure (ft^3)

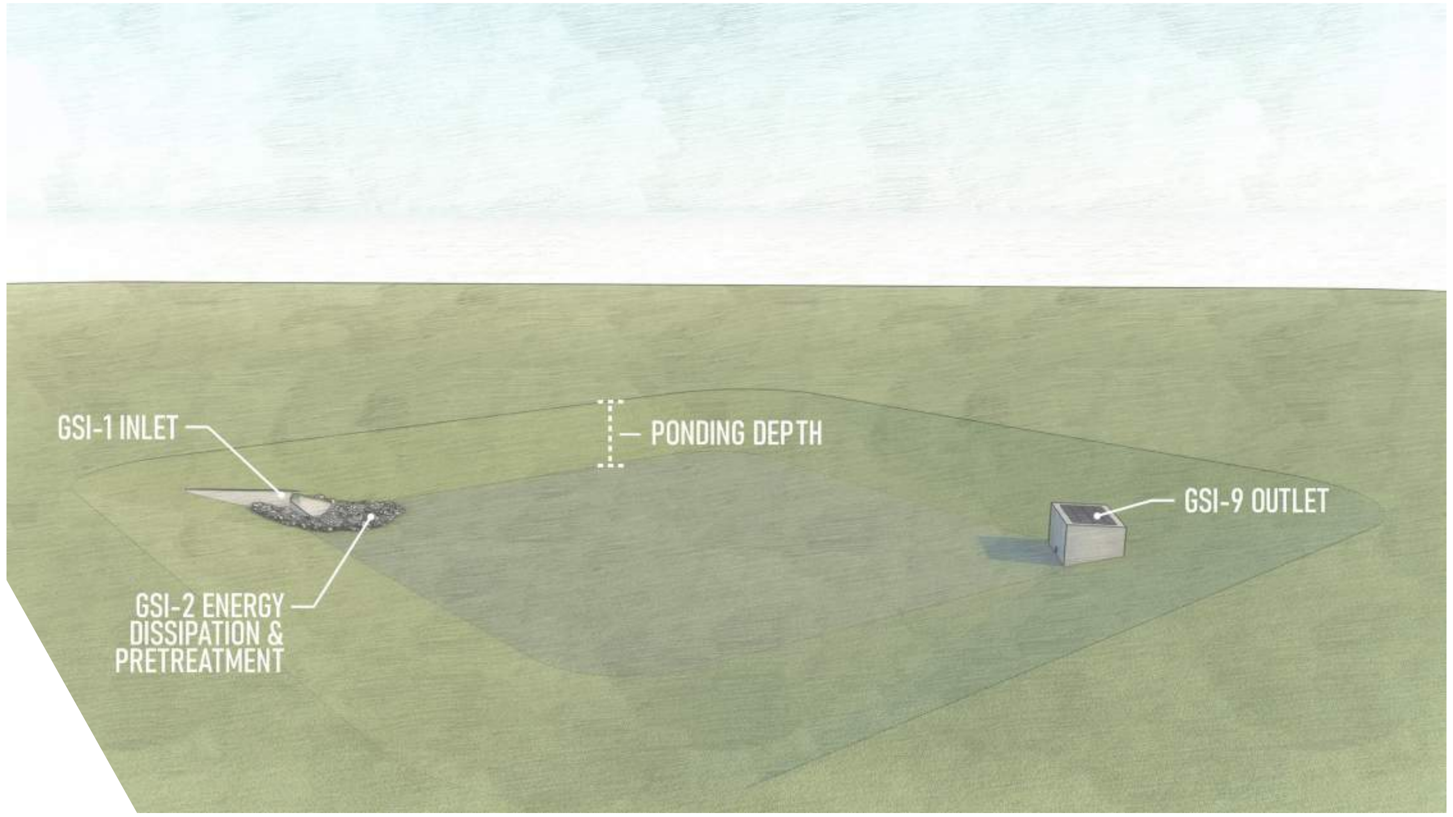
Equation 5605-21:

$$V_R = GSI_{RRF} * V_{GSI\ Storage}$$

V_R = Retention storage volume provided by retention practice (ft^3)

GSI_{RRF} = The GSI runoff reduction factor that represents the portion of the GSI storage volume that provides the credited retention benefits (%)

Figure 5605-8: Dry Detention Basin



Design Considerations:

- The maximum temporary ponding depth above the primary outlet structure shall be specified such that this storage volume can be dewatered within 72 hours after the end of the rainfall event, based on the outlet configuration. If detention basin is used to meet retention requirements, the retention volume must be drawn down within 72 hours via infiltration or over 72 hours via an underdrain and the 2-year storm must be drawn down over 24-72 hours as well.
- Detention basin side slopes are recommended to be 4:1 (H:V) or shallower to mitigate erosion potential. Side slopes shall not exceed 3:1 (H:V) without permanent stabilization measures. Overflow spillway shall include permanent stabilization measures capable of withstanding anticipated flows for the 100-year design storm.
- Provide maintenance access based on the equipment needed to maintain the facility and its components. Designer shall consider long-term maintenance responsibility and capacity when selecting GSI practice and components, as required per Section 5609.
- Designer should consider micro-drainage to facility side slopes and permanently reinforce landscape areas likely to receive concentrated flow from adjacent or nearby pavement areas.
- Designer should site the outlet as far from inflow point(s) into the dry detention basin as possible to prevent collected stormwater from short-circuiting the facility. Where the inlet and outlet must be located near each other, a berm or peninsula shall be incorporated to extend the flowpath through the basin.
- Designer must specify pre-construction infiltration testing per Specification Section 02956 to verify that in-situ subgrade saturated hydraulic conductivity reflects design assumptions.
- Designer should specify post-construction infiltration testing per Specification Section 02956 to verify that soil hydraulic conductivity reflects design assumptions after final grading is completed.
- A separation distance of 2 feet is required between the bottom of the dry detention basin and the seasonally high groundwater table or bedrock elevation.

Typical GSI Components:

At a minimum, dry detention basin practices include inlet, pretreatment, area protection, growing media, landscaping, piping, and outlet design components. Designers should also consider components required to route stormwater to, through, and out the dry detention basin during varying design storms. Below is a matrix showing the typical design components that make up dry detention basins.

Dry Detention Basin - GSI Component Matrix										
GSI-1	GSI-2	GSI-3	GSI-4	GSI-5	GSI-6	GSI-7	GSI-8	GSI-9	GSI-10	GSI-11
X	X	X			X	X	X	X		X

The following components should be considered when designing a dry detention practice. The list below provides general applicability and use considerations as it relates to the GSI Practice. Design considerations, design deliverable checklists, design detail templates, and reference to construction specifications, as applicable, for each component are included in the associated sections and should be referenced for detailed design.

GSI-1 Inlets, Section 5606.1

- Inlets may be used to collect and route stormwater into a dry detention basin. Inlets may collect stormwater upstream of the basin and route stormwater to the GSI via piping components (GSI- 8).

GSI-2 Energy Dissipation & Pretreatment, Section 5606.2

- Energy dissipation must be provided at inflow point(s) to the dry detention basin to reduce erosion within the basin.
- Dry detention basin must incorporate a sediment forebay for pretreatment to capture sediment, trash, and debris prior to entering the basin and for consolidated maintenance activities. To make sediment removal easier, the bottom and side slopes of the forebay may be lined with concrete, tied-concrete-block mats or similarly stable material

GSI-3 Area Protection (Optional), Section 5606.3

- Area protection may be placed at the edge of the dry detention basin to signal a difference in vegetation for maintenance purposes.
- Area protection must be used any time there is a significant change in grade or elevation between the dry detention basin and the surrounding area, to limit access to the GSI, or for safety purposes, as needed.

GSI-6 Media Liners (Optional), Section 5606.6

- GSI-6.1 Permeable Liner: Designer should specify permeable liner(s) if necessary for certain types of energy dissipation and/or landscaping purposes.

GSI-7 Landscaping, Section 5606.7

- The role of plant species is to bind nutrients and other pollutants by plant uptake, to remove water through evapotranspiration, and to create pathways for infiltration through root development and plant growth. Root growth provides a media that fosters bacteriologic growth, which in turn develops a healthy soil structure.
- GSI-7.8 Existing Tree Protection: Designer must consider the impact to existing trees, specify protection measures for existing trees and root systems when possible, and incorporate tree replacements into the landscape plan when existing tree removal is necessary.
- GSI-7.10 Planting Plan: If detention basin is used to meet retention requirements, designer must specify drought and inundation-tolerant native vegetation for the basin bottom and side slopes.

GSI-8 Piping, Section 5606.8

- Provide piping from the inlets (GSI-1) to the dry detention basin.
- GSI-8.1 Underdrain: An underdrain is required when dry detention basin is used to meet retention requirements, unless infiltration testing results demonstrate that the required 72-hour drawdown time can be met by subsurface in-situ soil conditions. When an underdrain is necessary, designer shall use an adjustable flow control mechanism, such as a valve or upturned elbow on the underdrain, or a manufactured outlet control structure with inline weir (GSI-9.2) to maximize retention and/or detention capabilities and to provide adaptability to post-construction site conditions and performance. Connect the underdrain or overflow structure to the site's stormwater conveyance system, or outfall to a suitable nonerosive location.
- GSI-8.3 Cleanout: If an underdrain is included, designer must provide cleanouts or other accessible structure for maintenance access to the underdrain. At a minimum cleanouts or other access structures must be included at the upstream and downstream end of the underdrain, at flow control mechanisms (if applicable), and at any transitions, fittings, or bends in the alignment.

- GSI-8.4: Observation Well: Designer must include an observation well to provide the owner with an access point to monitor the water level in the media volume and to understand the GSI performance. When an underdrain is included, cleanouts may also serve as observation wells.
- GSI-8.5 Anti-Seep Collar: Anti-seep collars must be specified for all pipes through material subject to saturation and seepage within earthen embankments. If an underdrain is included, designer should consider an anti-seep collar to reduce preferential flow of stormwater from the underdrain pipe bedding and aggregate backfill to adjacent subgrade or adjacent underground utility corridors, especially in instances where an impermeable liner is also specified.

GSI-9 Outlets, Section 5606.9

- GSI-9.1 Overflow Outlet: Designer must use an overflow outlet to control the ponding depth above the permanent pool in the dry detention basin and/or to allow for discharge of stormwater greater than the design event to the receiving system.
- GSI-9.2 Outlet Control Structure: Designer must specify an outlet control structure capable of maintaining the required drawdown time and release rates for the various design storms.
  - **Primary control structure**: shall be designed to control the 2-year design storm. If the dry detention basin is utilized to meet retention requirements, the primary control structure must draw down the 2-year storm over 24-72 hours.
  - **Secondary control** structure: shall be designed to control the 10-year and up to the 100-year design storms
  - **Overflow spillway**: shall be sized to safely pass rainfall events larger than the design capacity of the wetland. Overflow spillway shall be designed to control the 100-year design storm.
- Outlet structures shall be protected by trash racks, well screens, grates, stone filters, submerged inlet pipes to the outflow structure, or other approved devices to minimize clogging potential and frequency of structure.
- Outlet structures shall have a minimum opening size of 1". If the required release rate results in an opening size < 4", the opening must be protected by a submerged inlet pipe with stone filter or set in a weir control structure within the outlet control structure. If the required release rate results in an opening size <1", the maximum allowable release shall be equal to the release rate achieved with a 1" opening.

GSI-11 Internal Control, Protection, & Stabilization, Section 5606.11

- Control, protection, and stabilization measures are required to safeguard the GSI practices and components against erosion and sedimentation from the contributing site during construction and into establishment.

G. Subsurface Storage

Description:

Subsurface storage is a stormwater management practice where captured stormwater runoff is conveyed to an underground system for temporary storage and subsequent release back to the receiving system. Subsurface storage **GSI practices** typically include larger open storage chambers (GSI-10) to meet targeted storage volumes while maintaining intended site use function at the surface. Stormwater stored within the GSI is either temporarily detained and released through an outlet structure, allowed to infiltrate through the bottom of the GSI, or a combination of both. The use of subsurface storage alone to meet retention and detention requirements is discouraged. Whenever possible, other GSI practices should be considered.

GSI Storage & Sizing Calculations:

The majority of stormwater storage for subsurface storage GSI is typically provided in the storage chamber (GSI-10). Volume calculations for storage chambers will be specific to the manufactured product selected, and should follow manufacturer guidelines for sizing of the GSI system. Subsurface storage may also include additional storage volume in storage aggregate media layers around the storage chambers, as applicable. Subsurface GSI storage is generally calculated as the total storage volume for each of its components, as follows:

Subsurface storage can also provide peak flow reduction for larger design storms with an outlet structure designed to meet **required release rates**. When utilizing subsurface storage to meet **detention** requirements, it is recommended that sizing and storage be determined using a dynamic stormwater model. The detention storage should be sized to optimize stormwater detention requirements for the **required retention volume (RRV)** as well as the peak flow rate requirements for larger storm events, as applicable.

If **continuous monitoring and adaptive controls (CMAC)** technology is used to optimize storage and function of the GSI practice, the CMAC-controlled volume above the primary outlet structure elevation may be factored into the storage volume provided by the retention practice.

Equation 5605-22:

$$V_{GSI\ Storage} = V_S + V_{m,\ storage\ aggregate\ media}$$

V_S = Storage volume of storage chamber(s). (Note: for manufactured products this storage calculation will likely be product specific, and manufacturer guidelines should be followed for storage calculations.)

$V_{m.\ storage\ aggregate\ media}$ = Media storage volume of storage aggregate media

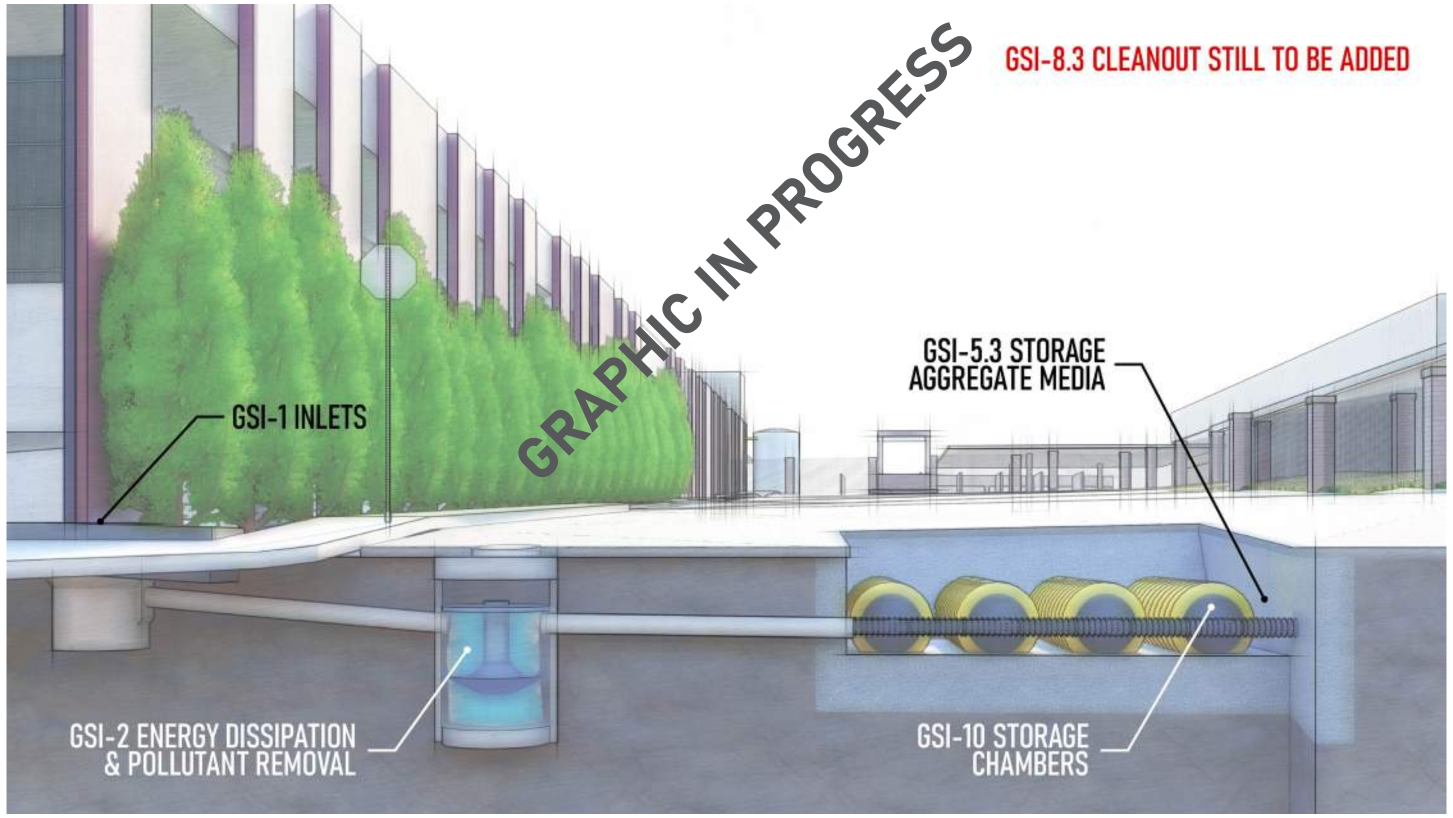
Equation 5605-23:

$$V_R = GSI_{RRF} * V_{GSI\ Storage}$$

V_R = Retention storage volume provided by retention practice (ft^3)

GSI_{RRF} = The GSI runoff reduction factor that represents the portion of the GSI storage volume that provides the credited retention benefits (%)

Figure 5605-9: Subsurface Storage



Design Considerations:

- Subsurface storage location may not be allowed within public right-of-way. Designer shall confirm with approving jurisdiction prior to specifying subsurface storage within public right-of-way.
- A registered engineer shall provide calculations or manufacturer's certification stating that the system meets the required design loading requirements.
- If propriety system is used, design shall include manufacturer's standards and specifications
- Subsurface storage material shall include a storage chamber component per GSI-10 (**Section 5606.10**)
- Determine if in-situ soil infiltration rate is high enough to allow for the subsurface retention storage to be infiltrated within the required draw down time. If subsurface storage is used to meet retention requirements, the retention volume must be drawn down within 72 hours via infiltration or over 72 hours via an underdrain and the 2-year storm must be drawn down over 24-72 hours as well.
- Specify pre-construction in-situ soil infiltration testing per Specification Section 02956 to verify that in-situ subgrade saturated hydraulic conductivity reflects design assumptions.
- Specify anti-flotation mechanisms to reduce effects of buoyancy if recommended by the manufacturer.
- Provide maintenance access based on the equipment needed to maintain the facility and its components. Designer shall consider long-term maintenance responsibility and capacity when selecting GSI practice and components, as required per Section 5609. Locate and size access points based on the equipment needed to maintain the facility and its components.

Typical GSI Components:

At a minimum, subsurface storage practices include inlet, pretreatment, soil and aggregate media, piping, and outlet design components. Designers should also consider components required to route stormwater to, through, and out the subsurface storage during varying design storms as well as components needed for designed surface restoration. Below is a matrix showing the typical design components that make up subsurface storage systems.

Subsurface Storage - GSI Component Matrix

GSI-1	GSI-2	GSI-3	GSI-4	GSI-5	GSI-6	GSI-7	GSI-8	GSI-9	GSI-10	GSI-11
X	X	X		X	X	X	X	X	X	X

The following components should be considered when designing a subsurface storage practice. The list below provides general applicability and use considerations as it relates to the GSI Practice. Design considerations, design deliverable checklists, design detail templates, and reference to construction specifications, as applicable, for each component are included in the associated sections and should be referenced for detailed design.

GSI-1 Inlets, Section 5606.1

- Inlets are necessary to provide a way for stormwater to enter the storage chamber (GSI-10). Often traditional stormwater inlets will be used with piping components (GSI-8) conveying stormwater into the subsurface storage.

GSI-2 Energy Dissipation & Pretreatment, Section 5606.2

- Provide pretreatment for sediment and debris prior to introducing flow into the storage chamber (GSI-10) to remove trash, debris, and sediment.

GSI-4 Permeable Pavements (Optional), Section 5606.4

- Permeable pavement may be utilized as an inlet to collect and convey stormwater into the storage chamber (GSI-10) and to provide pollutant removal.

GSI-5 Soil & Aggregate Media, Section 5606.5

- GSI-5.3 Storage Aggregate Media: Designer must specify a storage aggregate media that meets storage chamber (GSI-10) manufacturer requirements (as applicable).
- GSI-5.4 Choker Course (Optional): Designer must specify a choker course between the surface media layer and the storage aggregate media layer (GSI-5.3) such that the particle size of the choker course is less than the particle size of the storage aggregate media. Designer may include the choker course in the storage volume calculations, if applicable.

GSI-6 Media Liners (Optional), Section 5606.6

- GSI-6.1 Permeable Liner: Certain manufacturers of storage chambers (GSI-10) may require or recommend the use of a permeable liner for stabilization; designer should specify the type and class of permeable liner that conforms to manufacturer requirements.
- GSI-6.2 Impermeable Liner: If the GSI is adjacent to traditional pavement within the public right-of-way or a building, an impermeable liner shall be placed along the side of the GSI adjacent to the pavement or building. The impermeable liner shall extend a minimum depth below the GSI section such that the existing features are not within the infiltration zone of influence. The infiltration zone of influence is defined by the area within a 1:1 (H:V) slope line from the outer edge of the subsurface storage section.

GSI-7 Landscaping (Optional), Section 5606.7

- GSI-7.8 Existing Tree Protection: Designer must consider the impact to existing trees and root systems, specify protection measures for existing trees when possible, and incorporate tree replacements into the landscape plan when existing tree removal is necessary.

GSI-8 Piping, Section 5606.8

- GSI-8.1 Underdrain: An underdrain may be required (depending on the subsurface storage system) unless infiltration testing results demonstrate that the retention volume can be drawn down within 72 hours. When an underdrain is necessary, designer shall use an adjustable flow control mechanism, such as a valve or upturned elbow on the underdrain, or a manufactured outlet control structure with inline weir (GSI-9.2) to maximize retention and/or detention capabilities and to provide adaptability to post-construction site conditions and performance.

- GSI-8.3 Cleanout: Designer must integrate cleanouts in the system. These may be for maintenance access to the subsurface storage chamber(s), or to the underdrain. A minimum of two access points shall be provided. Designer should consider if one access/cleanout for each chamber row is necessary for access to maintain the entire system.
- GSI-8.4: Observation Well: Designer must include an observation well to provide the owner with an access point to monitor the water level in the subsurface storage and to understand the GSI performance. Cleanouts may also serve as observation wells.

GSI-9 Outlets, Section 5606.9

- GSI-9.2 Outlet Control Structure: Designer must configure outlet control structure(s) to control the discharge of stormwater to the receiving system, to maximize retention storage volumes, and to provide adaptability to post-construction site conditions and performance.
- When subsurface storage is used to meet retention requirements and infiltration rates are not sufficient, the outlet control structure must be designed to draw down the retention volume over 72 hours
- If subsurface storage is used to meet detention requirements, designer must specify an outlet control structure capable of maintaining the required drawdown time and release rates for the various design storms.
  - **Primary control structure:** shall be designed to control the 2-year design storm if subsurface storage is utilized to meet detention requirements.
  - **Secondary control structure:** shall be designed to control the 10-year and up to the 100-year design storms if subsurface storage is utilized to meet detention requirements
  - **Overflow spillway:** shall be sized to safely pass rainfall events larger than the design capacity of the subsurface storage. If subsurface storage is utilized to meet detention requirements, overflow spillway shall be designed to control the 100-year design storm.

GSI-10 Storage Chambers, Section 5606.10

- Specify a storage chamber product that provides the desired storage volume based on site space constraints to meet retention and/or detention requirements.

GSI-11 Internal Control, Protection, & Stabilization, Section 5606.11

- Control, protection, and stabilization measures are required to safeguard the GSI practices and components against erosion and sedimentation from the contributing site during construction and into establishment.

H. Green Roof

Description:

A green roof is an enhancement to a traditional roof system that includes additional waterproofing, drainage, and soil layers with vegetation. The drainage layer is typically a proprietary product that enhances the storage of stormwater between the growing media and waterproofing layers. The type of vegetation depends on the depth of growing media and the atmospheric conditions. Extensive green roofs generally consist of a thin soil layer, up to 6 inches deep, planted with shallow-rooted vegetation, while intensive green roofs have a soil layer greater than 6 inches deep and can sustain a variety of vegetation types. Green roofs may be modular systems made of trays or built-in-place.

GSI Storage & Sizing Calculations:

Green roofs provide stormwater storage in the growing media and the drainage layers. Green roof GSI storage is generally calculated as the total storage volume for each of its storage components, as follows:

Volume calculations for green roof media and the drainage layer are unique in that they do not use the porosity of the material. Instead, the **maximum water retention** value shall be applied. The maximum water retention value is a measure of how well a green roof holds on to water. The maximum water retention of a green roof product must be determined using the methods described by ASTM tests E2397, E2398, or E2399, as appropriate.

Equation 5605-24:

$$V_{GSI\ Storage} = V_{m,\ growing\ media} + V_{drainage\ layer}$$

$V_{m,growing\ media}$ = Media storage volume of growing media

$V_{drainage\ layer}$ = Storage volume of drainage layer

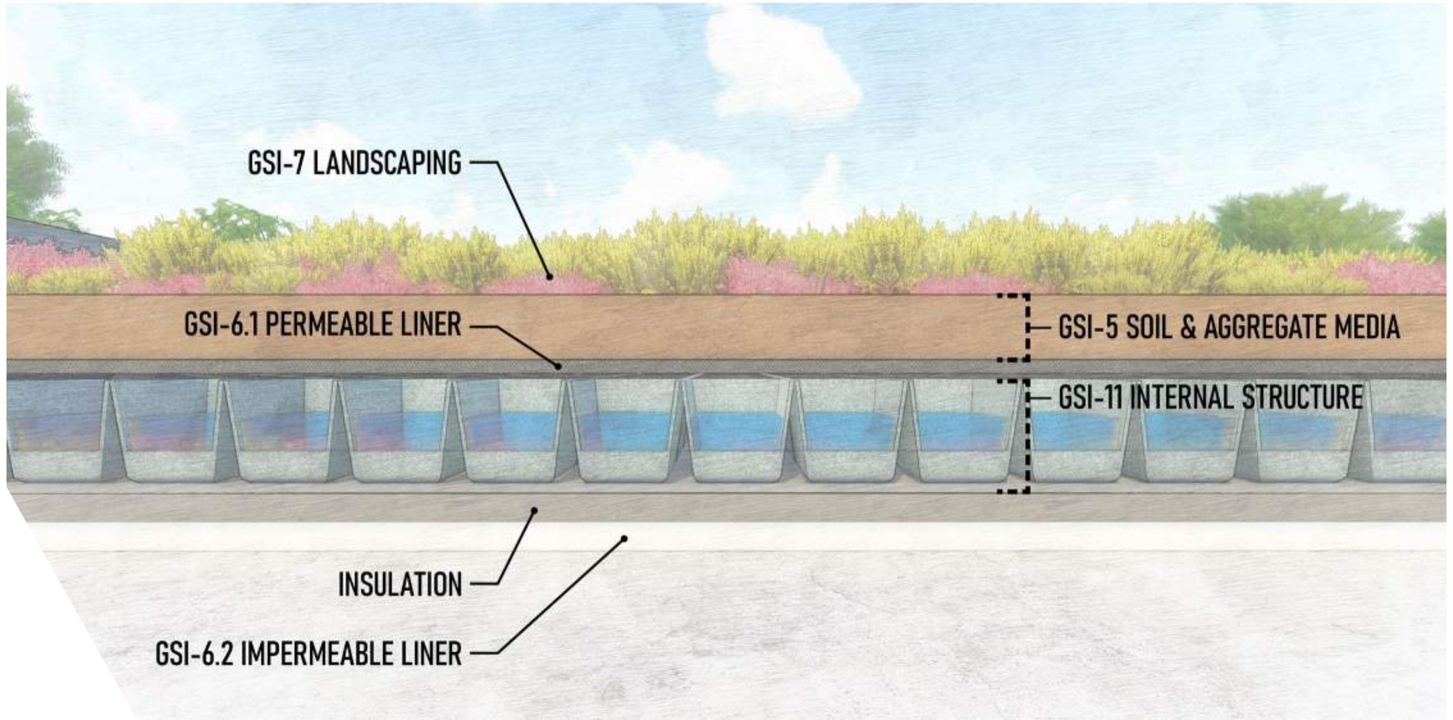
Equation 5605-25:

$$V_R = GSI_{RRF} * V_{GSI\ Storage}$$

V_R = Retention storage volume provided by retention practice (ft^3)

GSI_{RRF} = The GSI runoff reduction factor that represents the portion of the GSI storage volume that provides the credited retention benefits (%)

Figure 5605-10: Green Roof



Design Considerations:

- Structural design of the roof system is a critical consideration for both new green roofs and retrofit designs and requires the seal of a registered structural engineer. Consider the structural condition of the existing roof system in a retrofit application when designing a green roof. Coordinate the structural design of the roof system and the green roof design for a new installation. Roof loading calculations for the green roof should include all the design components plus the weight of the volume of water that the green roof is designed for.
- Designer should develop a project-specific specification for the green roof and related products. Specify a manufactured green roof system or specify green roof components to meet stormwater storage requirements.
- Maximum loading ratio of total drainage area to green roof area is 1.5:1.
- Runoff draining to a green roof from any outside areas must enter at the top surface of the green roof.
- Provide maintenance access based on the equipment needed to maintain the facility and its components. Designer shall consider long-term maintenance responsibility and capacity when selecting **GSI practice** and components, as required per **Section 5609**. Consider access for establishment and maintenance of vegetation and include irrigation, as applicable. Irrigation may be necessary during plant establishment and periods of drought, but green roofs designed to provide stormwater retention should not be regularly irrigated. Access to irrigation for green roof establishment and drought conditions must be provided.
- Vegetation should be designed for 90% landscape coverage within 12 months of planting.
- Green roof design, at a minimum, must comply with the following standards, as applicable:
  - American National Standard Institute (ANSI) RP-14 Wind Design Standard for Vegetated Roofing Systems to mitigate wind uplift and wind scour potential
  - ANSI VF-1 Fire Design Standard for Vegetative Roofs
  - ANSI VR-1 Procedure for Investigating Resistance to Root Penetration
  - International Building Code for roof assemblies and rooftop structures
  - International Plumbing Code for roof drainage
- Designer must consult local codes and regulations for location-specific compliance considerations for green roof applications.

Typical GSI Components:

At a minimum, green roof practices include area protection, growing media, media liners, landscaping, piping, and outlet design components. Designers should also consider components required to route stormwater through and out the green roof during varying design storms. Below is a matrix showing the typical design components that make up a green roof system.

Green Roof - GSI Component Matrix										
GSI-1	GSI-2	GSI-3	GSI-4	GSI-5	GSI-6	GSI-7	GSI-8	GSI-9	GSI-10	GSI-11
		X		X	X	X		X		X

The following components should be considered when designing a green roof practice. The list below provides general applicability and use considerations as it relates to the GSI Practice. Design considerations, design deliverable checklists, design detail templates, and reference to construction specifications, as applicable, for each component are included in the associated sections and should be referenced for detailed design. Manufactured green roof systems have product- specific components that should follow manufacturer requirements. Some or all of the following components may be applicable to the green roof design, even if the designer specifies a manufactured green roof system.

GSI-3 Area Protection, Section 5606.3

- Area protection must be placed at the edge of the green roof to signal the extents of the facility.

GSI-5 Soil & Aggregate Media, Section 5606.5

- GSI-5.1 Growing Media: Designer must specify a green roof growing media that meets the storage volume (maximum water retention), and nutrient needs of the specified vegetation, is resistant to wind uplift and scour, and does not exceed the structural limitations of the roof.
- Lightweight engineered soils are typically used for green roofs with a minimum depth of 2-1/2 inches. Lightweight engineered soils shall be thoroughly homogenized prior to placement on the green roof.

GSI-6 Media Liners, Section 5606.6

- GSI-6.1 Permeable Liner: Designer should specify a permeable geotextile liner to protect the waterproofing impermeable geomembrane liner and/or to prevent soil migration into the drainage layer.
- GSI-6.2 Impermeable Liner: Designer must specify an impermeable geomembrane liner for waterproofing. If the impermeable geomembrane liner is not root resistant, designer should consider specifying an additional geomembrane liner to prevent root penetration.

GSI-7 Landscaping, Section 5606.7

- GSI-7.10 Planting Plan: Designer must specify vegetation based on the depth and type of green roof growing media, climate, and irrigation available for establishment. Due to the challenging growing conditions present on many green roofs, native plants are not used as frequently as in other GSI practices.

GSI-9 Outlets, Section 5606.9

- Designer must specify an outlet structure to discharge volumes exceeding the designed capacity of the green roof to the roof drain system.

GSI-10 Storage Chambers (Optional), Section 5606.10

- GSI-10.5 Green Roof Drainage Layer: Many green roofs include a drainage layer that provides extra water storage while facilitating efficient drainage of water volumes that exceed the storage capacity of the green roof system.

GSI-11 Internal Control, Protection, & Stabilization, Section 5606.11

- Control, protection, and stabilization measures are required to safeguard the GSI practices and components against erosion and sedimentation from the contributing site during construction and into establishment.

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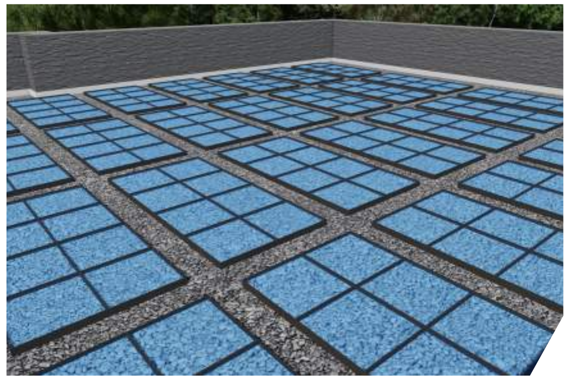
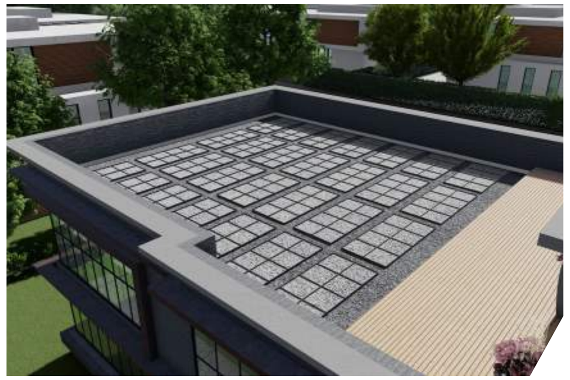
I. Blue Roof





Description:

A blue roof is an enhancement to a traditional roof system to provide for stormwater storage. A blue roof differs from a green roof in that a green roof is a vegetated system that relies on a growing media for storage while a blue roof is a non-vegetated system that stores stormwater in open space on the rooftop or within storage aggregate media. Blue roofs require additional waterproofing to the traditional roof and may be modular systems or built-in- place.

GSI Storage & Sizing Calculations:

Blue roofs provide stormwater storage in the ponding and/or storage aggregate media layers. Blue roof GSI storage is calculated as the total storage volume for each of its storage components, as follows:

Equation 5605-26:

$$V_{GSI\ Storage} = V_P + V_{m,\ storage\ aggregate\ media}$$

V_P = Ponding volume

$V_{m,growing\ media}$ = Media storage volume of storage aggregate media (Note: for modular systems this storage calculation will likely be product specific, and manufacturer guidelines should be followed for storage calculations.)

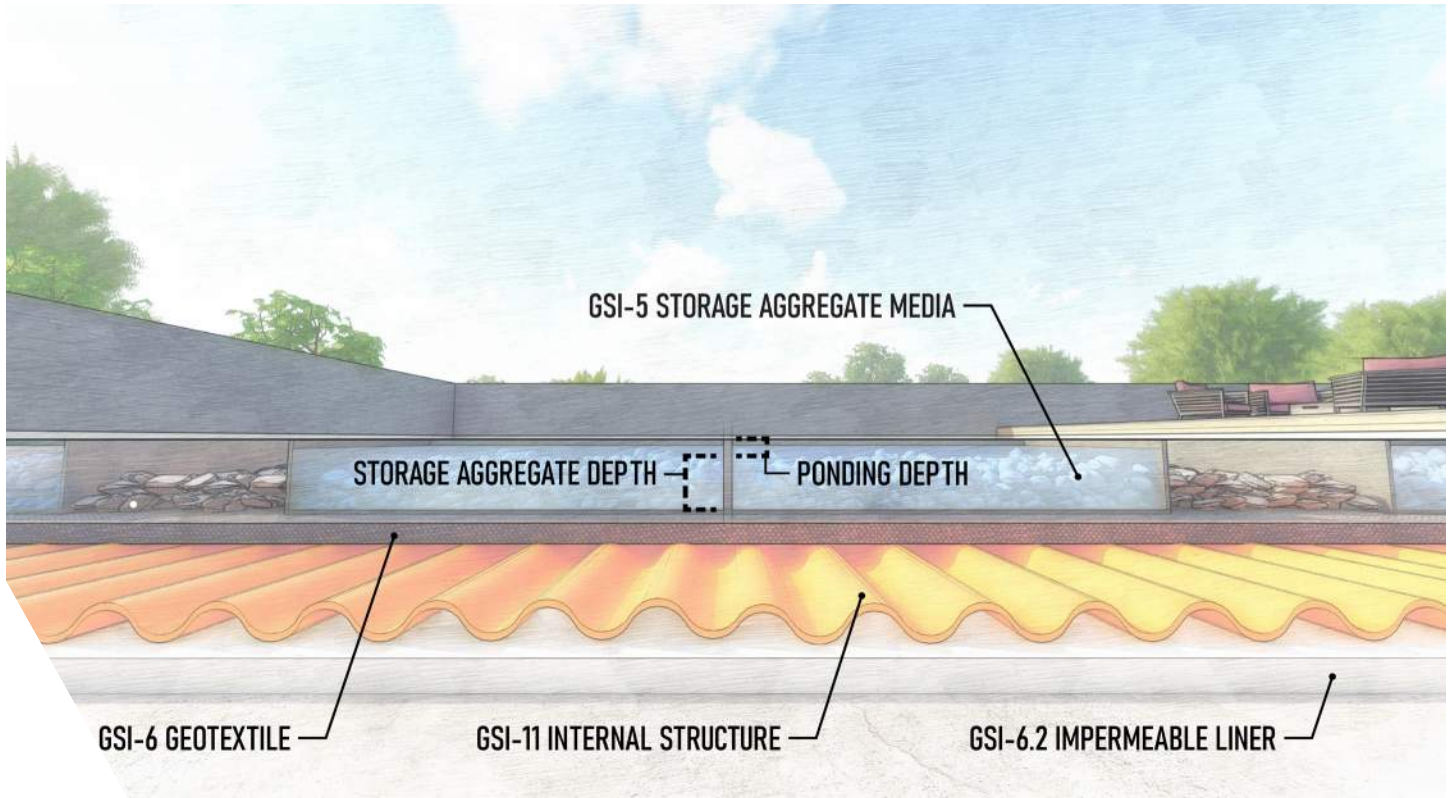
Equation 5605-27:

$$V_R = GSI_{RRF} * V_{GSI\ Storage}$$

V_R = Retention storage volume provided by retention practice (ft^3)

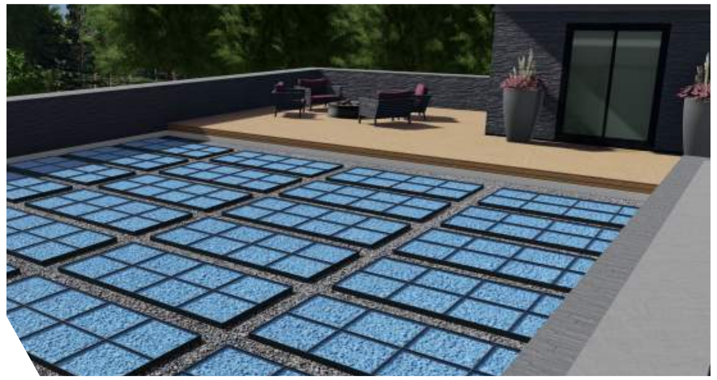
GSI_{RRF} = The GSI runoff reduction factor that represents the portion of the GSI storage volume that provides the credited retention benefits (%)

Figure 5605-11: Blue Roof



Design Considerations:

- Structural design of the roof system is a critical consideration for both new blue roofs and retrofit designs and requires the seal of a registered structural engineer. Consider the structural condition of the existing roof system in a retrofit application when designing a blue roof. Coordinate the structural design of the roof system and the blue roof design for a new installation.
- The blue roof storage volume must be shallow enough that it will fully evaporate within 72 hours.
- Designer should develop a project-specific specification for the blue roof and related products. Specify a manufactured blue roof system or specify blue roof components to meet stormwater storage requirements.
- Blue roof design, at a minimum, must comply with the following standards, as applicable:
  - International Building Code for roof assemblies and rooftop structures
  - International Plumbing Code for roof drainage
- Designer must consult local codes and regulations for location-specific compliance considerations for blue roof applications.
- Provide maintenance access based on the equipment needed to maintain the facility and its components. Designer shall consider long-term maintenance responsibility and capacity when selecting GSI practice and components, as required per **Section 5609**.



Typical GSI Components:

At a minimum, blue roof practices include area protection, storage aggregate media, media liners, and outlet design components. Designers should also consider components required to route stormwater through and out the blue roof during varying design storms. Below is a matrix showing the typical design components that make up a blue roof system.

Blue Roof - GSI Component Matrix										
GSI-1	GSI-2	GSI-3	GSI-4	GSI-5	GSI-6	GSI-7	GSI-8	GSI-9	GSI-10	GSI-11
		X		X	X			X		X

The following components should be considered when designing a blue roof practice. The list below provides general applicability and use considerations as it relates to the GSI Practice. Design considerations, design deliverable checklists, design detail templates, and reference to construction specifications, as applicable, for each component are included in the associated sections and should be referenced for detailed design. Manufactured blue roof systems have product-specific components that should follow manufacturer requirements. Some or all of the following components may be applicable to the blue roof design, even if the designer specifies a manufactured blue roof system.

GSI-3 Area Protection, Section 5606.3

- Area protection must be placed at the edge of the blue roof to signal the extents of the facility.

GSI-5 Soil & Aggregate Media (Optional) , Section 5606.5

- GSI-5.3 Storage Aggregate Media: Designer must specify storage aggregate media that meets the storage volume (porosity), is resistant to wind uplift and scour, and does not exceed the structural limitations of the allowable roof load.

GSI-6 Media Liners, Section 5606.6

- GSI-6.2 Impermeable Liner: Designer must specify an impermeable geomembrane liner for waterproofing.

GSI-9 Outlets, Section 5606.9

- Designer must specify an outlet structure to discharge volumes exceeding the designed capacity of the blue roof to the roof drain system.

GSI-11 Internal Control, Protection, & Stabilization, Section 5606.11

- Control, protection, and stabilization measures are required to safeguard the GSI practices and components against erosion and sedimentation from the contributing site during construction and into establishment.

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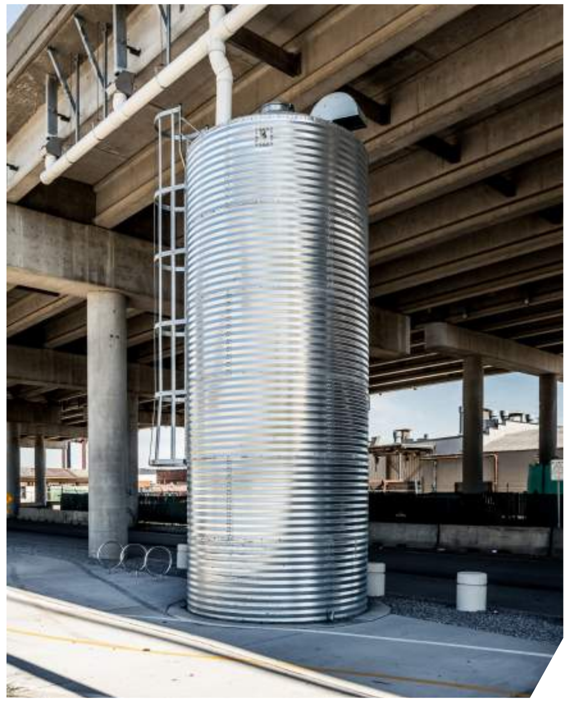
J. Cistern



Description:

A cistern is a storage tank that provides stormwater storage either above ground or below ground for rainwater harvesting applications. A collection pipe system often captures and conveys stormwater runoff from roof drainage or other elevated impervious area to the cistern for temporary storage. An additional pump or gravity outlet system may also be provided to convey the water for reuse in non-potable applications.

GSI Storage & Sizing Calculations:

Volume calculations for cisterns will be specific to the manufactured product selected and should follow manufacturer guidelines for sizing of the GSI system. Cistern storage is calculated as the total storage volume for each of its components, as follows:

Equation 5605-28:

$$V_{GSI\ Storage} = V_{Cistern}$$

$V_{Cistern}$ = Storage volume of cistern(s) at the time of the rainfall even. Designer should consider dewatering plan for cistern when calculating cistern storage volume. Available storage of the cistern may be limited by the volume of stormwater that remains from previous event(s).

Equation 5605-29:

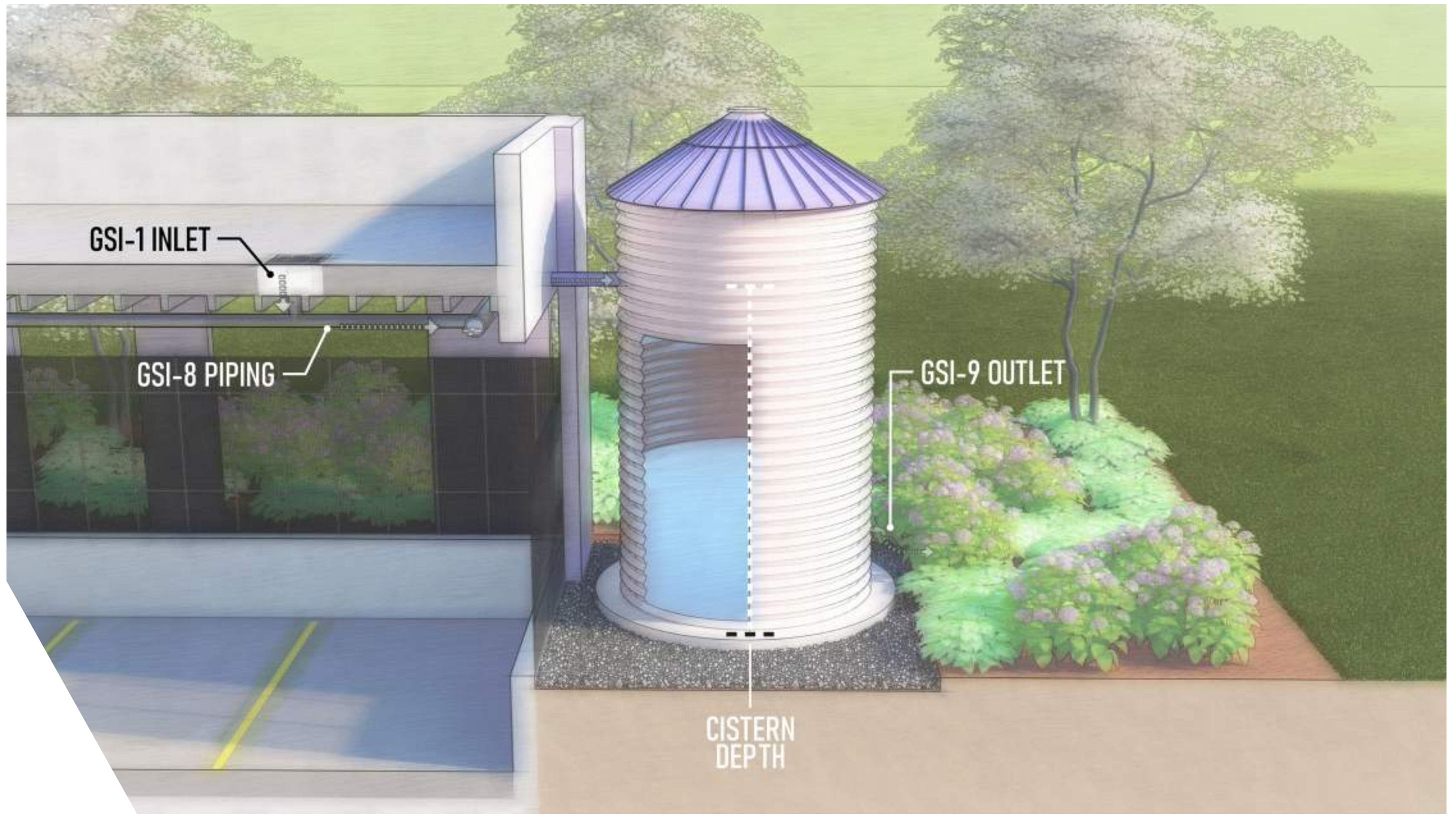
$$V_R = GSI_{RRF} * V_{GSI\ Storage}$$

V_R = Retention storage volume provided by retention practice (ft^3)

GSI_{RRF} = The GSI runoff reduction factor that represents the portion of the GSI storage volume that provides the credited retention benefits (%)

Cisterns only provide stormwater storage beyond the first filling of the cistern if the stored water is partially or fully used between rain events. If the cistern is not regularly emptied then no stormwater storage capacity is provided for subsequent storms.

Figure 5605-12: Cistern



Design Considerations:

- Identify a designated (non-potable) stormwater reuse application, such as irrigation. Some applications, like decorative fountains, may require treatment such as filtration or ultraviolet (UV) radiation and/or other means, depending on whether human contact with the water is anticipated. The Water Environment and Reuse Foundation Report: Risk-Based Framework for the Development of Public Health Guidance for Decentralized Non-Potable Water Systems contains robust guidance for developing a treatment system for harvested rainwater.
- Sizing of cisterns must consider both required storage volume as well as supply and demand needs for designated reuse.
- Designer must provide a maintenance plan including regular/intermittent dewatering of the cistern to maintain stormwater storage capacity for recurring rainfall.
- Designer shall consider long-term maintenance responsibility and capacity when selecting GSI practice and components, as required per **Section 5609**. Provide maintenance access; locate and size the system with consideration of the equipment needed to maintain the system and its components (for example, checking the piping for leaks, removing debris from the collection system, dewatering the cistern).
- Consider placement of cistern in relation to surrounding site use including pedestrian and bicycle access.
- Comply with the International Building Code and/ or local building codes and ordinances.
- When appropriate, provide permanent signage to notify users that the stored water is non-potable.
- Permanent signage should also include activation and drain/winterization dates, as applicable. For example, "Activate in April, Drain and Leave Exit Valve Open in November".
- Adhere to manufacturer recommendations when specifying a manufactured system.

Typical GSI Components:

At a minimum, cistern practices include inlet, pretreatment, piping, and outlet components. Designers should also consider components required to route stormwater to, through, out, and/or around the bioretention during varying design storms. Below is a matrix showing the typical design components that make up cisterns.

Cistern - GSI Component Matrix										
GSI-1	GSI-2	GSI-3	GSI-4	GSI-5	GSI-6	GSI-7	GSI-8	GSI-9	GSI-10	GSI-11
X	X						X	X	X	X

The following components should be considered when designing a cistern practice. The list below provides general applicability and use considerations as it relates to the GSI Practice. Design considerations, design deliverable checklists, design detail templates, and reference to construction specifications, as applicable, for each component are included in the associated sections and should be referenced for detailed design. Manufactured cistern systems typically have product-specific components that should follow manufacturer requirements. Additional components not typical of other GSI practices may also be required, such as foundation design and anchoring. If designer does not specify a manufactured cistern product, the following components may be applicable to the cistern design:

GSI-1 Inlets, Section 5606.1

- Inlets provide a way to collect stormwater before conveyance to the cistern, such as roof drains on a building or other inlets in a parking garage. Collection of stormwater for cisterns may differ from the inlets used for other GSI practices.

GSI-2 Energy Dissipation & Pretreatment, Section 5606.2

- Provide pretreatment for sediment and debris prior to introducing flow into the cistern, such as screens or inlet catch baskets.

GSI-7 Landscaping, Section 5606.7

- GSI-7.8 Existing Tree Protection: Designer must consider the impact to existing trees and root systems, specify protection measures for existing trees when possible, and incorporate tree replacements into the landscape plan when existing tree removal is necessary.

GSI-8 Piping, Section 5606.8

- Provide piping from the inlets (GSI-1) to the cistern.
- Provide piping for conveyance of stored stormwater in the cistern to the designated reuse application, if applicable.

GSI-9 Outlets, Section 5606.9

- Discharge of stormwater for cisterns differs from the outlets used for other GSI practices and will typically include a spigot for gravity outlet or a pump, depending on reuse application and location. Cisterns can also overflow into other GSI practices. Include an overflow outlet to discharge stormwater runoff volume in excess of the cistern volume.

GSI-10 Storage Chambers (Optional), Section 5606.10

- Specify a cistern product that provides the desired storage volume based on site space constraints to meet requirements. If design consists of a below grade cistern system, storage chambers may be used.

GSI-11 Internal Control, Protection, & Stabilization, Section 5606.11

- Control, protection, and stabilization measures are required to safeguard the GSI practices and components against erosion and sedimentation from the contributing site during construction and into establishment.

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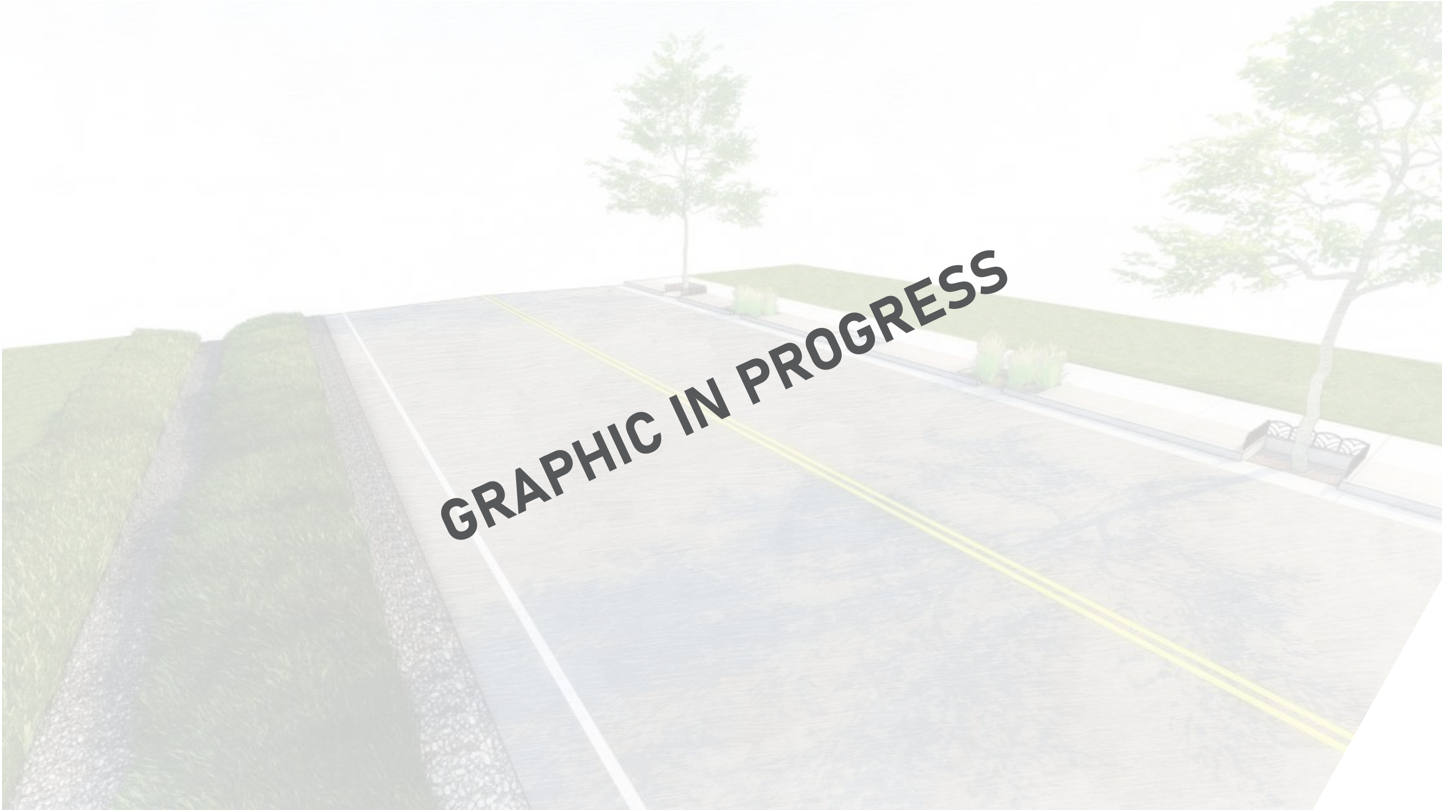
5605.3 STANDARDIZED ROADWAY GSI PRACTICES

The standardized roadway **GSI practices** are developed for a simplified approach to integrate GSI within the roadway applications. The designs define a standard footprint and storage components intended to be implemented without modification. These **GSI practices** are only intended for use on public roadway projects. The following standard roadway retention GSI practices are defined in this section:

- Stormwater Tree Planter
- Bioretention Planter
- Infiltration Trench
- Roadside Ditch Section

When stormwater tree planters, bioretention planters, or infiltration trenches are designed according to the spacing requirements in **Section 5607.3**, they are considered sufficient to meet the **retention volume (RRV)** for a public roadway project. Roadside ditch section sizing is described in section D below. Roadway retention may also be achieved using GSI practices presented in **Section 5605.2**.

Figure 5605-13 Standardized Roadway GSI Practices Cross Section



A. Stormwater Tree Planter

Description:

Stormwater tree planters are GSI practices that can be integrated into a roadway cross section, typically at the edges of the pavement and/or curb line. Each stormwater tree planter is comprised of Area Protection (GSI-3) to define the standard footprint and soil and aggregate media (GSI-5) to support the health of a tree. Except for the defined standard section, stormwater tree planters shall meet the requirements of bioretention practices and required GSI components defined in **Section 5605.2**.

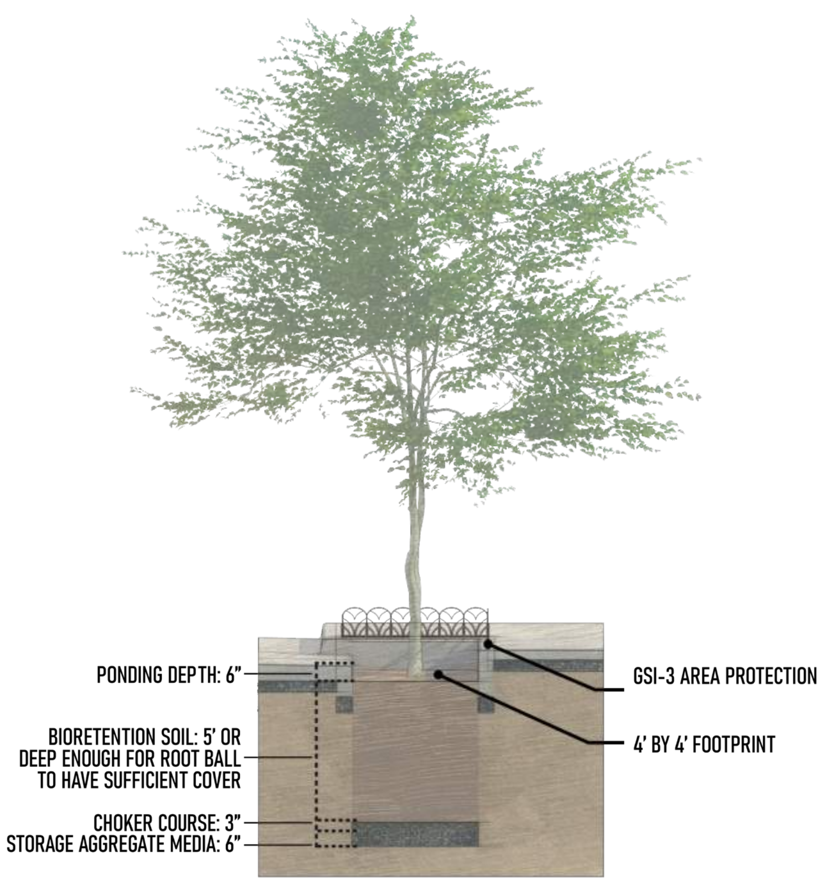
GSI Storage & Sizing Calculations:

The storage volume provided by the standard roadside stormwater tree planter is 41 cubic feet.

Design Considerations:

- The standard footprint of a stormwater tree planter is 4 feet by 4 feet.
- Ponding depth is 6 inches from the curb cut invert to the surface of the growing media.
- The entire volume of water stored in the stormwater tree planter must be drawn down over 72 hours.
- Stormwater tree planter is not a suitable GSI practice at locations where the water table is high or bedrock is present near the surface. A separation distance of 2 feet is required between the bottom of the excavated stormwater tree planter area and the seasonally high groundwater table or bedrock elevation.
- Stormwater tree planter facilities shall not be constructed within stream setbacks or in areas adjacent to streams where sediment may be deposited during frequent flood events.
- Provide maintenance access based on the equipment needed to maintain the facility and its components. Designer shall consider long-term maintenance responsibility and capacity when selecting GSI practice and components, as required per **Section 5609**.

Figure 5605-14: Stormwater Tree Planter Section Rendering



Typical GSI Components

At a minimum, the standard stormwater tree planter GSI practice includes growing media, landscaping and piping design components. Designers should also consider components required to route stormwater to, through, out, and/or around the GSI Practice during varying design storms. Below is a matrix showing the typical design components for bioretention.

Stormwater Tree Planter - GSI Component Matrix										
GSI-1	GSI-2	GSI-3	GSI-4	GSI-5	GSI-6	GSI-7	GSI-8	GSI-9	GSI-10	GSI-11
X		X		X	X	X	X	X		X

The following components should be considered when integrating the standard stormwater tree planter practice. The list below provides general applicability and use considerations as it relates to the GSI Practice. Design considerations, design deliverable checklists, design detail templates, and reference to construction specifications, as applicable, for each component are included in the associated sections and should be referenced for detailed design.

GSI-1 Inlets (Optional), Section 5606.1

- Inlets may be used to collect and route stormwater into the stormwater tree planter. If stormwater enters the GSI via sheet flow, an inlet component may not be required.

GSI-3 Area Protection, Section 5606.3

- Area protection such as ribbon curbs or mow strips should be placed at the edge of the stormwater tree planter to delineate the extents of growing media and to differentiate the vegetation for maintenance purposes.
- Area protection must be used any time the change in grade between the stormwater tree planter and the directly adjacent surface exceeds 12 inches, when adjacent slopes exceed 3:1 (horizontal: vertical), or to meet site specific safety requirements. Area protection techniques that provide vertical visual barriers are most appropriate for these conditions, such as curbs (GSI-3.1), fencing and railing (GSI-3.2), or stone barriers (GSI-3.4).

GSI-5 Soil & Aggregate Media, Section 5606.5

- GSI-5.1 Growing Media: Designer shall specify growing media as a minimum depth of 5 feet as per the standard detail, or a depth sufficient to cover the root ball of the tree.
- GSI-5.3 Storage Aggregate Media: Designer shall specify a storage aggregate media minimum depth of 6 inches, as per the standard detail. If an underdrain is included, sufficient depth of storage aggregate media shall be specified to meet minimum aggregate offset from underdrain piping per Section 5606.8, GSI-8.
- GSI-5.4 Choker Course: A choker course at a 3-inch depth between the growing media layer (GSI-5.1) and the storage aggregate media layer (GSI-5.3) per the standard detail.

GSI-6 Media Liners (Optional), Section 5606.6

- GSI-6.1 Permeable Liner: Designer should specify permeable liner(s) if necessary for certain types of energy dissipation, vertical separation between GSI media and adjacent subgrade, and/or landscaping purposes. Permeable liners are generally not recommended on horizontal GSI media layers due to tendency for microbial blinding that limits or even prohibits infiltration into the subsurface.
- GSI-6.2 Impermeable Liner: If the GSI is adjacent to traditional pavement within the public right-of-way or a building, an impermeable liner shall be placed along the side of the GSI adjacent to the pavement or building. The impermeable liner shall extend a minimum depth below the GSI section such that the existing features are not within the infiltration zone of influence. The infiltration zone of influence is defined by the area within a 1:1 (H:V) slope line from the outer edge of the subsurface storage section.

GSI-7 Landscaping, Section 5606.7

- The role of plant species is to bind nutrients and other pollutants by plant uptake, to remove water through evapotranspiration, and to create pathways for infiltration through root development and plant growth. Root growth provides a media that fosters bacteriologic growth, which in turn develops a healthy soil structure.
- GSI-7.8 Existing Tree Protection: Designer must consider the impact to existing trees and root systems, specify protection measures for existing trees when possible, and incorporate tree replacements into the landscape plan when existing tree removal is necessary.
- GSI-7.10 Planting Plan: Designer must consider the location within the stormwater tree planter and anticipated inundation depths and durations when specifying vegetation. Sun and shade tolerance, soil moisture tolerances, acceptable plant material sizes at maturity, and aesthetic expectations must also be considered based on the finished conditions around the GSI.

GSI-8 Piping, Section 5606.8

- GSI-8.4: Observation Well: Designer must include an observation well to provide the owner with an access point to monitor the water level in the media volume and to understand the GSI performance. When an underdrain is included, cleanouts may also serve as observation wells.

GSI-11 Internal Control, Protection, & Stabilization, Section 5606.11

- Control, protection, and stabilization measures are required to safeguard the GSI practice and components against erosion and sedimentation from the contributing site during construction and into establishment.

Figure 5605-15: Stormwater Tree Planter Standard Detail Template

B. Bioretention Planter

Description:

Standard bioretention planters are GSI practices that can be integrated into a roadway cross section, typically at the edges of the pavement and/or curb line. Each bioretention planter is comprised of Area Protection (GSI-3) to define the standard footprint and soil and aggregate media (GSI-5). An underdrain system integrated with the bioretention planter discharges to the stormwater management system. Except for the defined standard section, bioretention planters shall meet the requirements of bioretention practices and required GSI components defined in **Section 5605.2**.

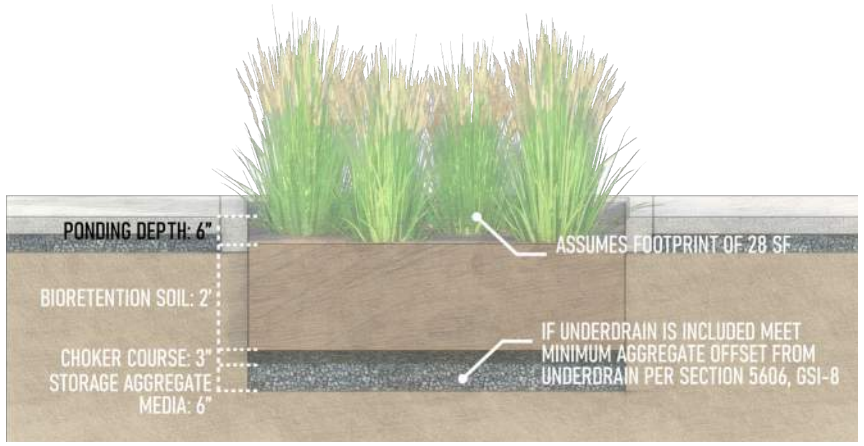
GSI Storage & Sizing Calculations:

The storage volume provided by the standard roadside bioretention planter is 41 cubic feet.

Design Considerations:

- The standard footprint of a bioretention planter is 28 square feet.
- Ponding depth is 6 inches from the curb cut invert to the surface of the growing media.
- The entire volume of water stored in the bioretention planter must be drawn down over 72 hours.
- Bioretention planter is not a suitable GSI practice at locations where the water table is high or bedrock is present near the surface. A separation distance of 2 feet is required between the bottom of the excavated stormwater tree planter area and the seasonally high groundwater table or bedrock elevation.
- Bioretention planter facilities shall not be constructed within stream setbacks or in areas adjacent to streams where sediment may be deposited during frequent flood events.
- Provide maintenance access based on the equipment needed to maintain the facility and its components. Designer shall consider long-term maintenance responsibility and capacity when selecting GSI practice and components, as required per **Section 5609**.

Figure 5605-16: Bioretention Planter Section Rendering



Typical GSI Components

At a minimum, the standard bioretention planter GSI practice includes, growing media, landscaping and piping design components. Designers should also consider components required to route stormwater to, through, out, and/or around the GSI Practice during varying design storms. Below is a matrix showing the typical design components for bioretention.

Bioretention Planter - GSI Component Matrix										
GSI-1	GSI-2	GSI-3	GSI-4	GSI-5	GSI-6	GSI-7	GSI-8	GSI-9	GSI-10	GSI-11
X		X		X	X	X	X	X		X

The following components should be considered when integrating the standard bioretention planter practice. The list below provides general applicability and use considerations as it relates to the GSI Practice. Design considerations, design deliverable checklists, design detail templates, and reference to construction specifications, as applicable, for each component are included in the associated sections and should be referenced for detailed design.

GSI-1 Inlets (Optional), Section 5606.1

- Inlets may be used to collect and route stormwater into the bioretention planter. If stormwater enters the GSI via sheet flow, an inlet component may not be required.

GSI-3 Area Protection, Section 5606.3

- Area protection such as ribbon curbs or mow strips should be placed at the edge of the bioretention planter to delineate the extents of growing media and to differentiate the vegetation for maintenance purposes.
- Area protection must be used any time the change in grade between the GSI Practice and the directly adjacent surface exceeds 12 inches, when adjacent slopes exceed 3:1 (horizontal: vertical), or to meet site specific safety requirements. Area protection techniques that

provide vertical visual barriers are most appropriate for these conditions, such as curbs (GSI-3.1), fencing and railing (GSI-3.2), or stone barriers (GSI-3.4).

GSI-5 Soil & Aggregate Media, Section 5606.5

- GSI-5.1 Growing Media: Growing media is 2 feet as per the standard detail.
- GSI-5.3 Storage Aggregate Media: Designer shall specify a storage aggregate media minimum depth of 6 inches, as per the standard detail. If underdrain is included, sufficient depth of storage aggregate media shall be specified to meet minimum aggregate offset from underdrain piping per Section 5606.8, GSI-8.
- GSI-5.4 Choker Course: A choker course at a 3-inch depth between the growing media layer (GSI-5.1) and the storage aggregate media layer (GSI-5.3) per the standard detail.

GSI-6 Media Liners (Optional), Section 5606.6

- GSI-6.1 Permeable Liner: Designer should specify permeable liner(s) if necessary for certain types of energy dissipation, vertical separation between GSI media and adjacent subgrade, and/or landscaping purposes. Permeable liners are generally not recommended on horizontal GSI media layers due to tendency for microbial blinding that limits or even prohibits infiltration into the subsurface.
- GSI-6.2 Impermeable Liner: If the GSI is adjacent to traditional pavement within the public right-of-way or a building, an impermeable liner shall be placed along the side of the GSI adjacent to the pavement or building. The impermeable liner shall extend a minimum depth below the GSI section such that the existing features are not within the infiltration zone of influence. The infiltration zone of influence is defined by the area within a 1:1 (H:V) slope line from the outer edge of the subsurface storage section.

GSI-7 Landscaping, Section 5606.7

- The role of plant species is to bind nutrients and other pollutants by plant uptake, to remove water through evapotranspiration, and to create pathways for infiltration through root development and plant growth. Root growth provides a media that fosters bacteriologic growth, which in turn develops a healthy soil structure.
- GSI-7.8 Existing Tree Protection: Designer must consider the impact to existing trees and root systems, specify protection measures for existing trees when possible, and incorporate tree replacements into the landscape plan when existing tree removal is necessary.
- GSI-7.10 Planting Plan: Designer must consider the location within the bioretention and anticipated inundation depths and durations when specifying vegetation. Sun and shade tolerance, soil moisture tolerances, acceptable plant material sizes at maturity, and aesthetic expectations must also be considered based on the finished conditions around the GSI.

GSI-8 Piping, Section 5606.8

- GSI-8.4: Observation Well: Designer must include an observation well to provide the owner with an access point to monitor the water level in the media volume and to understand the GSI performance. When an underdrain is included, cleanouts may also serve as observation wells.

GSI-11 Internal Control, Protection, & Stabilization, Section 5606.11

- Control, protection, and stabilization measures are required to safeguard the GSI practice and components against erosion and sedimentation from the contributing site during construction and into establishment.

Figure 5605-17: Bioretention Planter Standard Detail Template

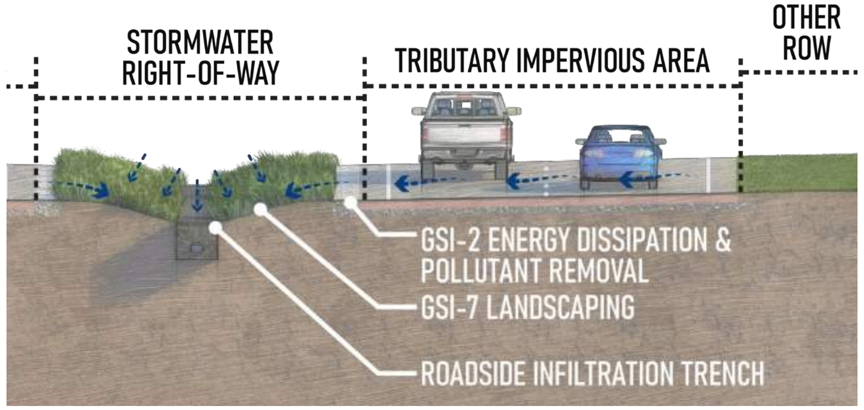
C. Roadside Infiltration Trench

Description:

Standard roadside infiltration trenches are GSI practices that can be integrated into a roadway cross section, typically at the edges of the pavement and/or curb line. Each trench is comprised of Area Protection (GSI-3) to define the standard footprint and aggregate media (GSI-5). An underdrain system integrated with the infiltration trench discharges to the stormwater management system. Except for the defined standard section, roadside infiltration trenches shall meet the requirements of bioretention practices and required GSI components defined in **Section 5605.2**.

Figure 5605-18: Roadside Infiltration Trench Section Rendering

Figure 5605-19: Example Cross Section - Roadside Infiltration Trench Section



GSI Storage & Sizing Calculations:

The storage volume provided by the standard roadside infiltration trench is 40 cubic feet.

Design Considerations:

- The standard footprint of a roadside infiltration trench is 24 square feet.
- Ponding is 6 inches from the curb cut invert to the surface of the storage aggregate.
- The entire volume of water stored in the roadside infiltration trench must be drawn down over 72 hours.
- Roadside infiltration trench is not a suitable GSI practice at locations where the water table is high or bedrock is present near the surface. A separation distance of 2 feet is required between the bottom of the excavated roadway infiltration trench area and the seasonally high groundwater table or bedrock elevation.
- Roadside infiltration trenches shall not be constructed within stream setbacks or in areas adjacent to streams where sediment may be deposited during frequent flood events.
- Provide maintenance access based on the equipment needed to maintain the facility and its components. Designer shall consider long-term maintenance responsibility and capacity when selecting GSI practice and components, as required per **Section 5609**.

Typical GSI Components

At a minimum, the standard roadside infiltration trench GSI practice includes storage aggregate media and piping design components. Designers should also consider components required to route stormwater to, through, out, and/or around the GSI Practice during varying design storms. Below is a matrix showing the typical design components for bioretention.

Roadside Infiltration Trench - GSI Component Matrix										
GSI-1	GSI-2	GSI-3	GSI-4	GSI-5	GSI-6	GSI-7	GSI-8	GSI-9	GSI-10	GSI-11
X		X		X	X		X	X		X

The following components should be considered when integrating the standard roadside infiltration trench practice. The list below provides general applicability and use considerations as it relates to the GSI Practice. Design considerations, design deliverable checklists, design detail templates, and reference to construction specifications, as applicable, for each component are included in the associated sections and should be referenced for detailed design.

GSI-1 Inlets (Optional), Section 5606.1

- Inlets may be used to collect and route stormwater into the roadside infiltration trench. If stormwater enters the GSI via sheet flow, an inlet component may not be required.

GSI-3 Area Protection, Section 5606.3

- Area protection such as ribbon curbs or mow strips should be placed at the edge of the roadside infiltration trench to delineate the extents of trench for maintenance purposes.
- Area protection must be used any time the change in grade between the GSI Practice and the directly adjacent surface exceeds 12 inches, when adjacent slopes exceed 3:1 (horizontal: vertical), or to meet site specific safety requirements. Area protection techniques that provide vertical visual barriers are most appropriate for these conditions, such as curbs (GSI-3.1), fencing and railing (GSI-3.2), or stone barriers (GSI-3.4).

GSI-5 Soil & Aggregate Media, Section 5606.5

- GSI-5.3 Storage Aggregate Media: Designer shall specify a storage aggregate media minimum depth of 3 feet, as per the standard detail.

GSI-6 Media Liners (Optional), Section 5606.6

- GSI-6.1 Permeable Liner: Designer should specify permeable liner(s) if necessary for certain types of energy dissipation, vertical separation between GSI media and adjacent subgrade, and/or landscaping purposes. Permeable liners are generally not recommended on horizontal GSI media layers due to tendency for microbial blinding that limits or even prohibits infiltration into the subsurface.
- GSI-6.2 Impermeable Liner: If the GSI is adjacent to traditional pavement within the public right-of-way or a building, an impermeable liner shall be placed along the side of the GSI adjacent to the pavement or building. The impermeable liner shall extend a minimum depth below the GSI section such that the existing features are not within the infiltration zone of influence. The infiltration zone of influence is defined by the area within a 1:1 (H:V) slope line from the outer edge of the subsurface storage section.

GSI-8 Piping, Section 5606.8

- GSI-8.1 Underdrain: An underdrain is required for bioretention planters. Connect the underdrain or overflow structure to the site's stormwater conveyance system, or outfall to a suitable nonerosive location.
- GSI-8.3 Cleanout: Designer must provide cleanouts or other accessible structures for maintenance access to the underdrain. At a minimum, cleanouts or other access structures must be included at the upstream and downstream end of the underdrain, at flow control mechanisms (if applicable), and at any transitions, fittings, or bends in the alignment.
- GSI-8.5 Anti-Seep Collar: Designer should consider an anti-seep collar to reduce preferential flow of stormwater from the underdrain pipe bedding and aggregate backfill to adjacent subgrade or adjacent underground utility corridors, especially in instances where an impermeable liner is also specified.

GSI-9 Outlets, Section 5606.9

- GSI-9.2 Outlet Control Structure: Designer shall use an adjustable flow control mechanism, such as a valve or upturned elbow on the underdrain, or a manufactured outlet control structure with inline weir (GSI-9.2.1 or GSI-9.2.2) to maximize retention capabilities and to provide adaptability to post-construction site conditions and performance. One adjustable flow control mechanism shall be specified for each roadside infiltration trench. Runoff in excess of the design volume bypasses the roadside infiltration trench on the roadway curb line.

GSI-11 Internal Control, Protection, & Stabilization, Section 5606.11

Control, protection, and stabilization measures are required to safeguard the GSI practice and components against erosion and sedimentation from the contributing site during construction and into establishment.

Figure 5605-20: Infiltration Trench Standard Detail Template

D. Roadside Ditch Sections

Description:

A roadside ditch section is a median, shoulder, or other portion of the right-of-way that directly receives stormwater runoff via sheetflow from tributary impervious areas. This **GSI practice** preserves or re-establishes vegetated areas, promoting infiltration while supplementing other stormwater management collection practices.

GSI Storage & Sizing Calculations:

The roadside ditch section has a defined footprint to be considered as an area for shallow infiltration and dispersion. Figures 5605-20 & 5605-21 illustrate this footprint.

Loading ratio and minimum roadside ditch section footprint design equations are shown as Equations 5605-30 & 5605-31.

If the roadside ditch section meets the design factors identified in Table 5605-2 and the minimum footprint requirement, then it is considered sufficient to meet the **retention volume (RRV)** for the portion of the roadway project in its tributary area.

Design Considerations:

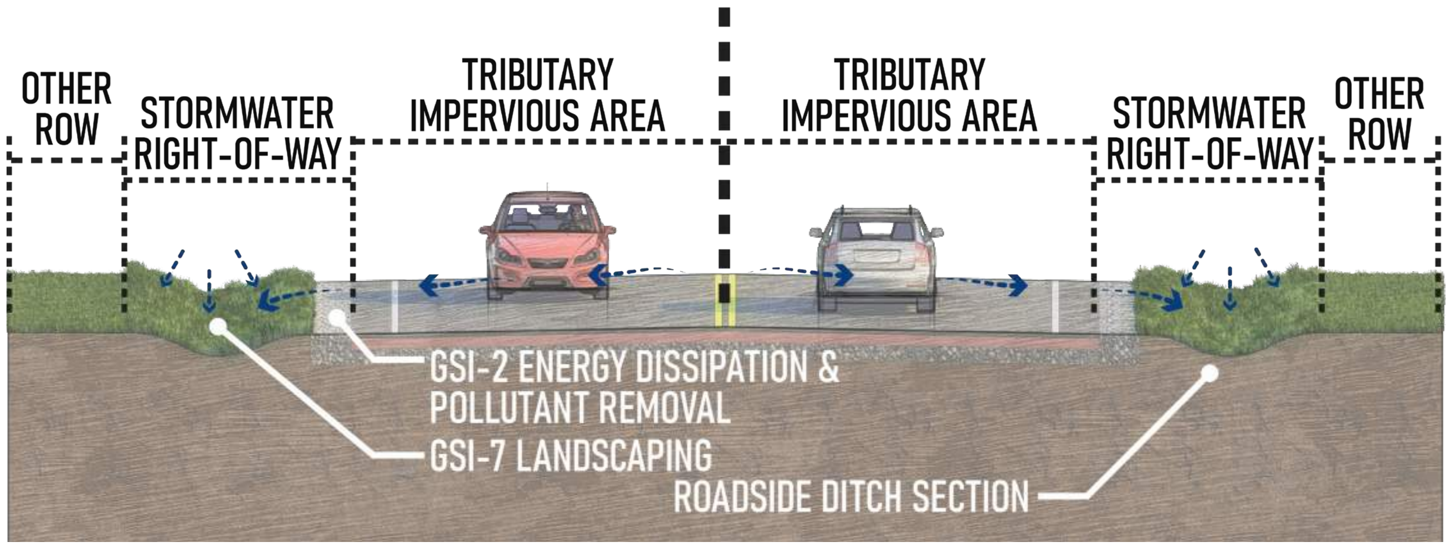
- Roadside ditch sections rely on sheet flow over a distance, typically at least 10 to 15 feet wide, to achieve maximum infiltration and meet the required loading ratio. They may therefore not be suitable for very restricted right-of-way widths.
- Compaction of the soils should be limited during construction and existing vegetation should be preserved to the extent practicable.
- Designer must specify pre-construction infiltration testing per Specification Section 02956 to verify that in-situ subgrade saturated hydraulic conductivity reflects design assumptions.
- Designer must specify post-construction infiltration testing per Specification Section 02956 to verify that infiltration rate of constructed roadside ditch reflects design assumptions.
- Robust vegetative growth is important to maintain infiltration rates, slow water, and stabilize the surface to prevent scour.
- Sheet flow conditions can be encouraged using a gravel area between the edge of pavement and the Roadside Ditch Sections, with the gravel area functioning as a level spreader and minimizing potential for erosion.
- Slopes should provide positive drainage away from the roadway, and be no steeper than 1V:3H.
- Longitudinal slopes or the profile grade through the vegetated area should allow more uniform dispersion and avoid the creation of high velocity flows that may result in erosion.
- Any cross culverts within the clear zone should have end sections flush with the slope.

Typical GSI Components

Table 5605-2: Roadside Ditch Section Design Factors

Typical Effective Ponding Depth	Typical Design Target Drawdown Time and Controlling Factor	Minimum Design Infiltration Rate for Full Infiltration	Maximum Loading Ratio to Capture RRV	Mounding Potential
0.2 to 0.5 ft	12 to 24 hours (plant survival; aesthetics)	0.1 to 0.5 in./h.	2:1 to 5:1 (20% to 50%)	Low

Figure 5605-21: Example Cross Section - Roadside Ditch Section on Shoulder



Equation 5605-30:

$$\text{Loading Ratio} = \frac{\text{Impervious Tributary Area}}{\text{GSI Footprint}}$$

Loading Ratio = The ratio of impervious tributary area to the GSI footprint area

$I_{\text{Tributary Area}}$ = Impervious area tributary to the GSI (ft²)

GSI Footprint = The surface area of the GSI measured from the edge of pavement to the flowline of the roadside ditch (ft²)

Equation 5605-31:

$$\text{Minimum GSI Footprint} = \frac{\text{Impervious Tributary Area}}{\text{Maximum Loading Ratio}}$$

Minimum GSI Footprint = Minimum surface area need to meet RRV requirements (ft²)

$I_{\text{Tributary Area}}$ = Impervious area tributary to the GSI (ft²)

Maximum Loading Ratio = Maximum ratio of impervious tributary area to GSI footprint necessary to meet RRV requirements (ft²)

At a minimum, the standard roadside ditch section GSI practice includes design and performance requirements for plant species used and control, protection and stabilization components. Designers should also consider components required to route stormwater to, through, out, and/or around the GSI Practice during varying design storms. These components must also take into account local and state requirements impacting the design. Below is a matrix showing the typical design components for roadside ditch sections.

Roadside Ditch Sections - GSI Component Matrix										
GSI-1	GSI-2	GSI-3	GSI-4	GSI-5	GSI-6	GSI-7	GSI-8	GSI-9	GSI-10	GSI-11
						X				X

The following components should be considered when integrating the standard roadside ditch section practice. The list below provides general applicability and use considerations as it relates to the GSI Practice. Design considerations, design deliverable checklists, design detail templates, and reference to construction specifications, as applicable, for each component are included in the associated sections and should be referenced for detailed design.

GSI-7 Landscaping, Section 5606.7

- ➔ The role of plant species is to bind nutrients and other pollutants by plant uptake, to remove water through evapotranspiration, and to create pathways for infiltration through root development and plant growth. Root growth provides a media that fosters bacteriologic growth, which in turn develops a healthy soil structure.
- ➔ GSI-7.8 Herbaceous Plants (Grasses): Designer must consider the impact to existing trees and root systems, specify protection measures for existing trees when possible, and incorporate tree replacements into the landscape plan when existing tree removal is necessary.
- ➔ GSI-7.10 Planting Plan: Designer must consider the location within ditch and anticipated inundation depths and durations when specifying vegetation. Sun and shade tolerance, soil moisture tolerances, acceptable plant material sizes at maturity, and aesthetic expectations must also be considered based on the finished conditions around the GSI.

GSI-11 Internal Control, Protection, & Stabilization, Section 5606.11

- ➔ Control, protection, and stabilization measures are required to safeguard the GSI practice and components against erosion and sedimentation from the contributing site during construction and into establishment.

5606

RETENTION & DETENTION COMPONENTS

5606 RETENTION & DETENTION COMPONENTS

While each **GSI Practice** is site specific, there are features that are common between facilities that assist in performing the retention and detention functions. These features, known herein **GSI Components**, are designed to bring stormwater in and out of the facility, protect the GSI, and promote its overall function. Components are the building blocks of a GSI facility. This manual includes some of the most common and typical GSI Components, but are not all-inclusive and should not limit designers from using alternative products and technologies. GSI Components discussed in this manual include:

GSI-1 Inlets: A collection point of stormwater, from an opening in the curb line to a traditional inlet.

GSI-2 Energy Dissipation & Pretreatment: Features to decrease the velocity of stormwater to prevent erosion and scouring of surface materials, and, to collect sediment, trash and debris.

GSI-3 Area Protection: Physical or visual barriers at the edge of the GSI.

GSI-4 Permeable Pavements: A hardscape surface that water can permeate and infiltrate into subsurface media. Permeable pavements can reduce impervious area.

GSI-5 Soil & Aggregate Media: The primary means of storage and filtration, allowing stormwater to move downward within the GSI facility. Finer and coarser graded media provide filtration and storage. Soil media supports plant growth, from grasses to trees.

GSI-6 Media Liners: Permeable or impermeable liners used to provide stabilization and/or separation between media types.

GSI-7 Landscaping: Provides a highly visible GSI function with benefits at and below the surface. Includes trees, shrubs, grasses, perennials, and native wildflower seeding and sodding.

GSI-8 Piping: To convey stormwater to or away, provide access or observation to the subsurface, and protect utilities within the GSI.

GSI-9 Outlets: A discharge point for excess stormwater volume, either above or below grade.

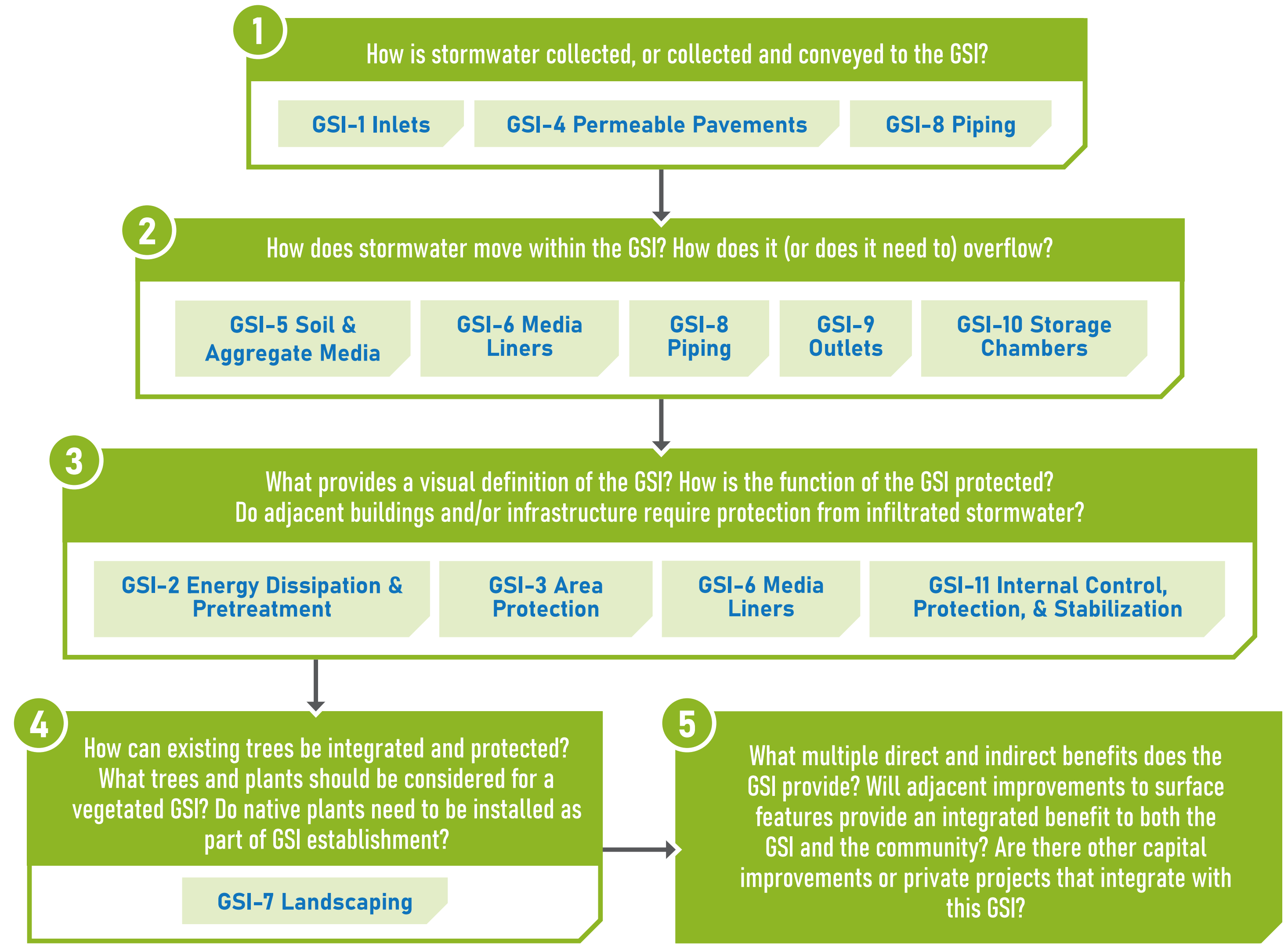
GSI-10 Storage Chambers: Structures that provide a large void volume for the storage of stormwater.

GSI-11 Internal Control, Protection, & Stabilization: Measures to protect the GSI site during construction and provide soil stabilization long-term.

GSI Practices are comprised of individual GSI Components required to provide the desired function of the facility. While each GSI site and design is unique, it is recommended that the following GSI Components be evaluated at a minimum for applicability for each of the GSI Practices:

	GSI Component										
	GSI-1	GSI-2	GSI-3	GSI-4	GSI-5	GSI-6	GSI-7	GSI-8	GSI-9	GSI-10	GSI-11
Bioretention	●	●	●		●	●	●	●	●		●
Permeable Pavement System			●	●	●	●	●	●	●	●	●
Infiltration Trench	●	●	●		●	●	●	●	●	●	●
Wetland	●	●	●		●	●	●	●	●		●
Wet Detention Basin	●	●	●			●	●	●	●		●
Dry Detention Basin	●	●	●		●	●	●	●	●		●
Subsurface Storage	●	●	●		●	●	●	●	●	●	●
Green Roof			●		●	●	●		●		●
Blue Roof			●		●	●			●		●
Cistern	●	●						●	●	●	●

Regardless of the GSI Practice, designers define the function of a GSI facility by assembling GSI Components. This can be described by thinking through the function of the final GSI and how stormwater can be managed and used for community benefit. For example:



For each GSI Component included in this section, a design guideline is provided including:

- **Component Overview**: definition and example photograph of the design component category
- **Design deliverables checklist**: outlines minimum required information that should be included on construction documents if design component is specified
- **Design Component Guideline**: includes a description of the types of components included in that category, where to use the GSI Component, and design considerations for specific applications of the component within GSI practices
- **Design Detail Template**: when applicable, a GSI Component design detail template is provided with the guideline in **Appendix G**. Designer shall be responsible for tailoring the detail template to each respective GSI design to include on the construction plans. The detail shows the minimum level of information that needs to be provided with the design. The designer is expected to consider the constructability of the detail during the design process in the project specific GSI setting. AutoCAD files are also available for each GSI Component detail.
- **GSI Construction Guide Specification**: when applicable, a GSI Construction Specification template is provided for the GSI Component in **Appendix H**. The GSI Construction Specifications are considered guides specifications with only portions of the specification intended to be edited by the designer. The GSI Construction Specifications are available in a SpecsIntact file format. Additional detail on how to use the GSI Construction Specifications can be found in the **Appendix**.

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5606.1 GSI-1 INLETS

An inlet is the collection point of stormwater. An inlet typically collects stormwater runoff and discharges this runoff either to the surface or below the surface of the GSI. An inlet component can range from simple openings in the curb line, to manufactured stormwater structures, to traditional inlet boxes.

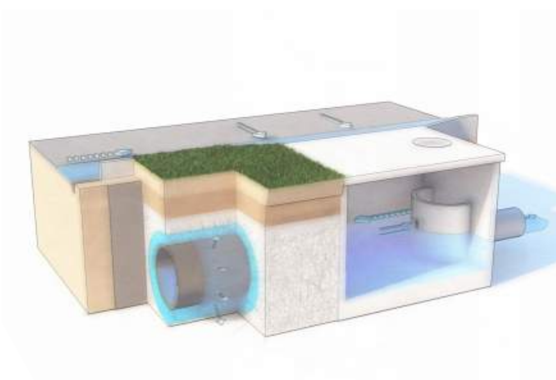
DESIGN DELIVERABLE CHECKLIST

- Plan view of **GSI Practice** indicating location of inlet structure(s) including northing/easting points.
- Spot elevations to show drainage path towards the inlet structure(s) as well as the **designated overflow route** and bypass for storm events that exceed the design capacity of the GSI Practice.
- Detail/Section view of inlet structure(s) specifying recommended product/manufacturer, size, dimensions, and elevations (as applicable).
- Detail of anchoring design to prevent flotation (as applicable).
- Inlet capacity calculations (if required to include on the design plans by the **approving jurisdiction**).

Inlets at 74th Street Rain Gardens

KC Water "THINK Protect Your Water Protect Your Home" Manhole Lid

Infiltration Inlet Rendering



1.1 INFILTRATION INLET

Description:

The infiltration inlet is a modification to a traditional stormwater inlet box that promotes infiltration by directing stormwater to a storage aggregate media layer over native soil subgrade. A distribution pipe or storage chamber component can be added for increased storage and infiltration capacity. Stormwater flows in excess of the design can be controlled with an overflow weir to a downstream conveyance system.

Where to Use:

The infiltration inlet can be used where stormwater inlet boxes are typically used to promote infiltration at a stormwater collection point for frequent rainfall events.

Design Considerations:

The following are recommendations and considerations for designing an infiltration inlet. Refer to Specification Section 02940 GSI Inlets for construction and material specific requirements.

- ➔ Street tree placement requirements shall be considered when siting and sizing infiltration inlets.
- ➔ Infiltration inlet shall be sized to capture the design storm for the tributary drainage area to that location. Adjustments to distribution pipe length and aggregate storage bed dimensions may be necessary.
- ➔ Impermeable liner is required adjacent to street pavement to impede water from encroaching into pavement subgrade.
- ➔ Maintenance access shall be considered when placing the inlet. If the inlet is located more than 20 feet from an existing vehicular access point, a maintenance access path shall be included with the design.

Infiltration inlet designs outside of the parameters of this guideline shall be submitted for review and approval.

1.2 CURB CUT

Description:

Curb cuts are openings that route stormwater from the curb line to the surface of the GSI. Curb cuts are poured in place concrete into a new curb line or as a new section of an existing curb line.

Where to Use:

Curb cuts can be used along any curb application to collect stormwater from pavement areas and direct toward a specific location in a GSI feature. Curb cuts are not recommended for use on curb radii and shall be located at or beyond the end of a curb return.

Impacts to ADA ramps shall be considered when placing curb cuts.

Design Considerations:

The following are recommendations and considerations for designing GSI with curb cuts. Refer to Specification Section 02940 GSI Inlets for construction and material specific requirements.

- ➔ A curb cut shall be designed with inlet capacity sufficient to intercept the design flow for the GSI Practice. On sloped applications, multiple curb cuts may be needed. Curb cut inlet capacity should limit the maximum inflow to the GSI facility to the design storm when possible, allowing for larger stormwater flows to bypass the facility.
- ➔ A curb cut should be used in conjunction with an energy dissipation and pretreatment component (GSI-2.1) to limit erosion of GSI surface materials.
- ➔ The invert of the curb cut shall be lower than or equal to the invert of the pavement tor gutter line. Gutter aprons (GSI-1.3) may be used in conjunction with curb cuts to maximize capture capacity of the curb cut.
- ➔ A curb guard (GSI-3.5) can extend the curb line over a curb cut at the designer's discretion.
- ➔ Maintenance access shall be considered when placing the inlet. If the inlet is located more than 20 feet from an existing vehicular access point, a maintenance access path should be included with the design.

A curb cut design outside of the parameters of this guideline shall be submitted for review and approval.

Curb Cut

Gutter Apron

1.3 GUTTER APRON

Description:

A gutter apron is a depression in the gutter line at a stormwater collection point to a GSI facility. The depression of the gutter apron is characterized by a steeper cross slope that can increase inlet capacity to maximize the volume of stormwater collected.

Where to Use:

A gutter apron can be used on any pavement section where spacing between the pavement edge and the GSI Practice allow. A gutter apron may be setback, or extended, behind the curb line to avoid conflict with traffic lanes. To avoid slip hazards for passengers exiting vehicles, gutter aprons are not recommended adjacent to on-street parking areas.

Design Consideration

The following are recommendations and considerations for designing GSI with a gutter apron component. Refer to Specification Section 02940 GSI Inlets for construction and material specific requirements.

- ➔ Gutter apron cross slope shall be specified by designer based on stormwater collection design and desired entrance velocity. Maximum gutter cross slope shall consider hazard to off-course vehicles. Gutter cross slope within a gutter apron shall not exceed 3:1 (H:V) along roadway applications.
- ➔ The use of directional veins within a gutter apron can provide some means of energy dissipation and assist in the collection of stormwater.

A gutter apron design outside of the parameters of this guideline shall be submitted for review and approval.

1.4 TRENCH DRAIN

Trench Drain

Description:

A trench drain is a solid or grated cover over a shallow concrete or metal trench that collects stormwater.

Typical applications either collect stormwater runoff from an adjacent paved surface at-grade through a grated cover, or, collect flow through an opening at one end of the trench. A trench drain often is used to collect stormwater without impacting the pedestrian or vehicular use of the surrounding area. Shallower invert elevations associated with a trench drain can provide greater flexibility than standard curb or grate inlets.

Where to Use:

A trench drain can be used in pedestrian or vehicular applications where stormwater collection is needed at-grade. A trench drain is commonly used to collect stormwater from the curb line and convey it across a walking surface without creating a hazard to pedestrians. A trench drain may also be used at street or driveway entrances to collect stormwater across the pavement section where a lack of elevation change may preclude other means of stormwater collection.

Trench drains may not be appropriate or allowable within public streets. Designer shall confirm with the approving jurisdiction prior to specifying a trench drain within public street applications.

Design Considerations:

The following are recommendations and considerations for designing GSI with a trench drain component. Refer to Specification Section 02940 GSI Inlets for construction and material specific requirements.

- ➔ A trench drain shall be rated for pedestrian or vehicular loading, as needed for the site-specific design application. H-20 loading is required for trench drains.
- ➔ When a trench drain is designed for a pedestrian application, grate spacing in the trench cover shall not exceed 1/2 inch per ADA Standards for Accessible Design. Designer shall verify that selected product complies with ADA requirements.
- ➔ Maintenance access shall be considered when placing the inlet. If the inlet is located more than 20 feet from an existing vehicular access point, a maintenance access path shall be included with the design.

A trench drain design outside of the parameters of this guideline shall be submitted for review and approval.

Manufactured Inlet

Manufactured Inlet

1.5 MANUFACTURED INLET

Description:

A manufactured inlet is a proprietary inlet structure that typically provides a pretreatment function in addition to stormwater collection. Some manufactured inlets can accomplish dual-purpose objectives that otherwise would require multiple GSI Components.

Where to Use:

A manufactured inlet may be used in stormwater collection applications. Designer shall consult manufacturer requirements and recommendations when determining where to use a specific manufactured inlet.

Design Considerations:

The following are recommendations and considerations for designing GSI with a manufactured inlet component. Refer to Specification Section 02940 GSI Inlets for construction and material specific requirements.

- A manufactured inlet design detail is often provided by the manufacturer. Designer shall review detail and provide additional information as needed for construction.
- Inlets adjacent to vehicular application shall be traffic rated.
- Design shall be per manufacturer instructions. Product shall provide adequate information to calculate inlet capacity.
- If applicable, designer shall provide an anchoring design for a manufactured inlet to mitigate flotation of the structure.
- Maintenance access shall be considered when placing the inlet. If the inlet is located more than 20 feet from an existing vehicular access point, a maintenance access path shall be included with the design.

Manufactured inlet pretreatment designs outside of the parameters of this guideline shall be submitted for review and approval.

1.6 FLOW CONTROL STRUCTURE

Description:

A flow control structure diverts runoff from the design storm into the GSI facility while allowing flows from larger rain events to bypass the GSI facility. GSI typically manages runoff from smaller design storms than traditional detention practices. These GSI facilities may be damaged by storm flows larger than the design event. Flow control structures can be used to control the flow rate and volume entering an offline GSI facility.

Where to Use:

Flow control structures shall be installed wherever a GSI Practice that is not intended or capable of handling flows larger than the design storm receives inflow from an enclosed stormwater collection system.

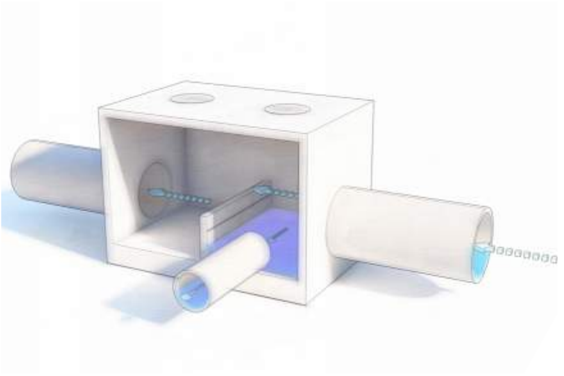
Design Considerations:

The following are recommendations and considerations for designing GSI with flow control structures. Flow control structures require unique detailed, site- specific design and therefore no GSI construction specification for Flow Control Structure is included in **Appendix H**. Designer shall provide a detail sheet depicting what should be constructed, specifying all critical elevations and/or depths. Designer shall also provide technical specifications for construction and material requirements if not covered by standard specifications.

- Flow control structures may utilize traditional standard storm structures with structural additions/modifications to divert stormwater flows.
- Structural design of flow control structure may be necessary.
- Manufactured products such as stop logs and valves may be used to control flow.
- Utilize back flow preventers if larger storm flows bypassing the GSI facility are discharging to the combined sewer system to prohibit backup of combined sewer flows into the GSI.
- Maintenance access shall be considered when placing the flow control structure and designing and sizing the components (e.g. access to clean structure and to add/remove stop logs).
- The flow control structure shall be sized to adequately convey larger flows bypassing the GSI facility.
- The pipe out to the GSI shall be sized to convey the design storm to the GSI facility while also considering the flow rate to the GSI facility during larger storm events intended to bypass the GSI facility.

Flow control structure designs outside of the parameters of this guideline shall be submitted for review and approval.

Flow Control Structure Rendering



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5606.2 GSI-2 ENERGY DISSIPATION & PRETREATMENT

The best method of introducing runoff to GSI is to allow the water to sheetflow into the facility over a grassed area to reduce inflow velocity and to reduce the sediment load entering the system. When sheetflow cannot be achieved, energy dissipation components shall be used to decrease the velocity of stormwater to prevent erosion and scouring of GSI surface materials. Pretreatment can be achieved using pretreatment components capture sediment, trash, and debris prior to entering the GSI to assist with maintenance of the facility. Energy dissipation can also serve as pretreatment by collecting debris where stormwater enters the GSI.

DESIGN DELIVERABLE CHECKLIST

- ➔ Plan view of **GSI Practice** indicating location of energy dissipation/pretreatment device including northing/ easting points for extents of component (as applicable).
- ➔ Detail/Section view of energy dissipation including aggregate and/or surface stone/brick size, depth, extents, and elevations (as applicable).
- ➔ Detail/Section view of pretreatment device including recommended product/manufacturer, size, dimensions, and elevations (as applicable).
- ➔ GSI designed maximum entrance velocity, permissible shear stress, and aggregate and/or stone size calculations (if required to include on the design plans by the **approving jurisdiction**).

Kansas City VA Medical Center

Concrete Embedded Splash Pad

Concrete Embedded Splash Pad

Surface Stone Splash Pad

2.1 SPLASH PADS

Description:

A splash pad uses surface stone or brick to dissipate stormwater energy. The roughness of the surface material reduces the velocity of the stormwater. Surface material for a splash pad can be installed over an aggregate bedding and media liner, or, may be embedded in concrete. Manufactured products such as tied-concrete-block mats or similarly anchored material are maintenance-friendly alternatives as well.

GSI 2.1.1 Concrete Embedded Splash Pad:

Splash pad in which the surface stone or brick is embedded in concrete.

GSI 2.1.2 Surface Stone Splash Pad:

Splash pad in which the surface stone is placed over a graded aggregate base.

Where to Use:

Energy dissipation shall be used in GSI applications where stormwater is channelized to an inlet (GSI-1). Splash pads may embed surface stone/brick in concrete for designs with a higher stormwater velocity, that require anchoring of the surface material. Both loose stone and concrete embedded splash pads may be used for either application, provided the size of the surface material and anchoring/base design is appropriate for the velocity of stormwater entering the GSI.

Design Considerations:

The following are recommendations and considerations for designing GSI with surface stone splash pads. Refer to Specification Section 02941 GSI Energy Dissipation and Pretreatment for construction and material specific requirements.

➔ The flow path of stormwater exceeding the design capacity of the GSI shall be considered during the design process. It is recommended that GSI be designed to only intercept design capacity flows, and to allow larger flows to bypass the facility. Preventing larger flows from being routed through the GSI reduces the risk for washout of the surface material during larger storm events.

➔ Energy dissipation shall be sized to withstand maximum shear stress for stormwater flow entering the GSI. Maximum shear stress shall consider flows for all storms allowed to pass through the GSI, regardless of the design storm the GSI is designed to control. Surface stone material shall be sized to prevent movement of the stone such that the design shear stress of the stormwater inflow is less than the permissible shear stress. Table 2.1 shows permissible shear stress for a variety of stone sizes.

➔ For surface stone sizes outside of the range provided, designer shall provide gradation requirements of the stone material and shear stress used for calculation.

➔ Side slopes towards the growing media are recommended to be 4:1 (H:V) or shallower to mitigate erosion potential. Slopes shall not exceed 3:1 (H:V).

➔ Energy dissipation shall be designed with sufficient length, width, and thickness to prevent and/or minimize scouring of the GSI surface media beyond the extents of the splash pad. The following are minimum recommendations for splash pad geometries:

» Width: The splash pad shall extend behind the GSI inlet a minimum of twice the width of the opening.

» Length: The splash pad shall extend beyond the GSI side slope onto the flat surface of the GSI a minimum of 3 times the thickness of the total splash pad.

» Thickness: The thickness of the surface material is recommended to be a minimum of twice the D stone.

Surface stone splash pad designs outside of the parameters of this guideline shall be submitted for review and approval.

Table 2.1 Surface Stone Permissible Shear Stress

Average Stone Size (in)	Permissible Shear Stress (lbs/ft^2)
1	0.33
2	0.67
3	0.87
4	1.36
6	2.00
10	3.46
12	4.00
18	6.17
20	6.77
30	10.15
39	13.53

Permissible shear stress value derived from Table 5608-3 (**Section 5608**) and critical shear stress values from Table 5610-3 (**Section 5610**).

Permissible shear stress is assumed to be critical shear stress with a 1.5 factor of safety applied.

Applied shear stress is calculated based on hydraulic radius of inflow at the inlet, surface slope, and specific weight of water, per **Section 5610.5, E**.

Inlet Catch Basket

Concrete Sediment Forebay

Hydrodynamic Seperator (MARC BMP Manual, 2012)

Catch Basin Insert (MARC BMP Manual, 2012)

2.2 PRETREATMENT

Description:

Pretreatment consists of at and below grade components upstream of the GSI that collect trash, sediment, and debris and serves as a pollutant removal mechanism for the GSI practice. Manufactured pretreatment devices are available in various sizes and applications, ranging from small capacity inlet catch baskets to larger structures with trash racks and settling chambers. Pretreatment can also be achieved by installing grass or clean aggregate buffer strips between the tributary drainage area and the GSI. Adequate pretreatment reduces maintenance needs within the GSI, improves aesthetics of the facility, and increases the sustainability of the overall function of the practice.

The following pretreatment devices are included in this manual:

- 2.2.1 Proprietary Media Filtration
- 2.2.2 Native Vegetation Swale
- 2.2.3 Vegetation Filter Strip
- 2.2.4 Sand Filter
- 2.2.5 Baffle Box/Grip Separator
- 2.2.6 Catch Basin Insert
- 2.2.7 Oil-Water Separator
- 2.2.8 Hydrodynamic Separator

Where to Use:

Pretreatment shall be considered on all GSI Practices. Size, type and extent of pretreatment needs vary by GSI design. Energy dissipation, grass buffer strips and inlet catch baskets may be adequate for smaller scale GSI. Larger scale, centralized GSI require more robust pretreatment to limit sediment loading and collect trash.

Some pretreatment devices are not permitted within the public right-of-way or on public projects. Designer shall confirm with the approving jurisdiction prior to specifying pretreatment device on pubic projects.

Design Considerations:

The following are general recommendations and considerations for designing GSI with pretreatment. Design consideration for specific types of pretreatment are discussed in the following subsections. Refer to Specifications Section 02941 Energy Dissipation and Pretreatment for construction and material specific requirements. Note that not all pretreatment components discussed herein are included in the specifications, and additional technical specifications may be required.

- Designer shall specify pretreatment component device/manufacturer for each GSI facility. The type of pretreatment selected for a given site will vary by downstream GSI facility or storm sewer system as well as site conditions including available space, existing infrastructure, and targeted pollutant.
- Pretreatment sizing shall be based on stormwater inflow and should consider a range of operational flows including the maximum design flow. For some pretreatment practices the water velocities should be evaluated for a range of design events including the maximum flow conditions to the practice. Follow manufacturer recommendations and criteria, as applicable.

- For manufactured pretreatment devices, specify a manufactured product or products capable of treating influent stormwater to desired limits of target pollutant(s) in effluent discharge for design event. Provide the design flow rate and confirm with manufacturer that the specified unit can provide the required treatment for that flow rate.
- Provide adequate stabilization and/or bypass for storm events greater than the design event. Bypass of larger storms shall be routed to locations, facilities or drainage systems with adequate capacity for the stormwater flows being received.
- Evaluate groundwater conditions and specify anti-flotation mechanisms to reduce effects of buoyancy (as applicable).
- Designer shall consider maintenance access and frequency of maintenance activities when selecting pretreatment measures. Pretreatment measures that require cleaning by a vehicle-mounted unit, such as a vacuum truck, must be within 10 feet of pavement that can accommodate the vehicle's size and weight

2.2.1 Proprietary Media Filtration

Proprietary media filtration are manufactured filtration systems that rely on a variety of mechanisms for pretreatment depending on the product and/or the type of media. Inert media rely on physical pretreatment processes only for filtration of suspended solids for water quality enhancement. Active media use chemical processes for pretreatment such as adsorption, absorption, and/or ion exchange to remove dissolved solids for water quality enhancement. For both types of media, treatment occurs when collected stormwater is routed through the media.

The effectiveness of the pretreatment is based on the contact time of the influent stormwater with the specified media prior to discharge and appropriate long-term maintenance. The type of media should be specified based on the target pollutant(s) for removal.

Proprietary Media Filtration

- Specify a manufactured product or products capable of treating influent stormwater to desired limits of target pollutant(s) in effluent discharge for design event.
- Provide a media type to treat target pollutant(s).
- Provide adequate contact time for effective removal of target pollutant(s).

2.2.2 Native Vegetation Swale

Native vegetation swales are flow paths used primarily for conveyance of stormwater that rely on sedimentation and filtration for water quality enhancement. Treatment occurs through settling and filtering of stormwater as it is conveyed through the vegetation along the swale. Native vegetation swales provide energy dissipation for smaller flows by reducing velocities as water moves through the native vegetation, which is typically comprised of grasses and grass-like plants.

Native Vegetation Swale

- Side slopes are recommended to be 4:1 (H:V) or shallower to mitigate erosion potential and ease maintenance. Side slopes shall not exceed 3:1 (H:V).
- Limit the depth of flow in the native vegetation swale to 4 inches for the design event.
- Limit the velocity of flow in the native vegetation swale to less than 3 feet per second for the design event.
- Vegetation should be established prior to stormwater flow being routed to the filter strip. This can be achieved by providing a bypass during the establishment period.
- Designer shall specify a growing media that meets vegetative needs of the pretreatment GSI Practice, as applicable.

2.2.3 Vegetation Filter Strip

Vegetated filter strips are shallow-graded/sloped vegetated sections that are typically adjacent to an impervious surface that rely on filtration for water quality enhancement. Filtration occurs when stormwater is routed through the vegetation as sheet flow from an upstream impervious area. Vegetated filter strips provide energy dissipation for smaller flows by reducing velocities as water moves through the vegetation.

Vegetated Filter Strip

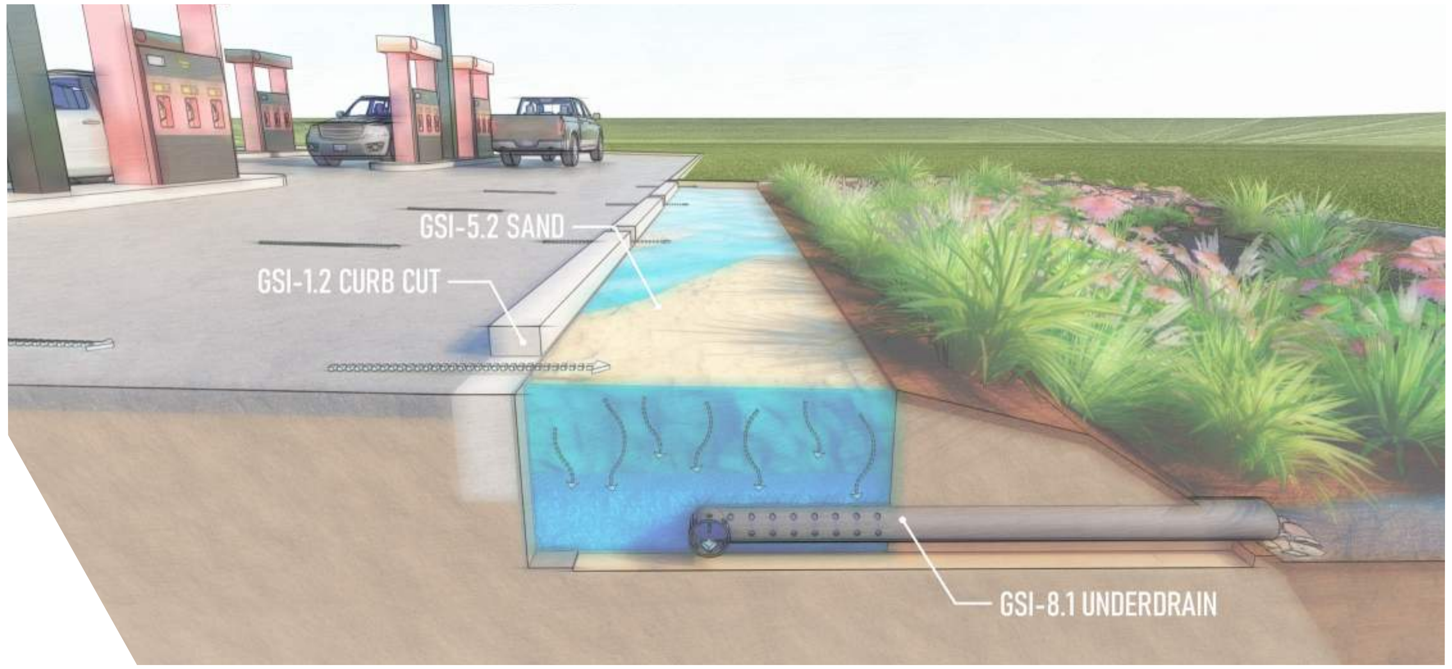
- Design vegetated filter strip such that flow entering and exiting the GSI Practice is sheet flow.
- Vegetation should be established prior to stormwater flow being routed to the filter strip. This can be achieved by providing a bypass during the establishment period.
- Designer shall specify a growing media that meets vegetative needs of the pretreatment GSI Practice, as applicable.

2.2.4 Sand Filter

Sand filters route stormwater through a sand media layer to provide filtration for water quality enhancement.

Sand Filter

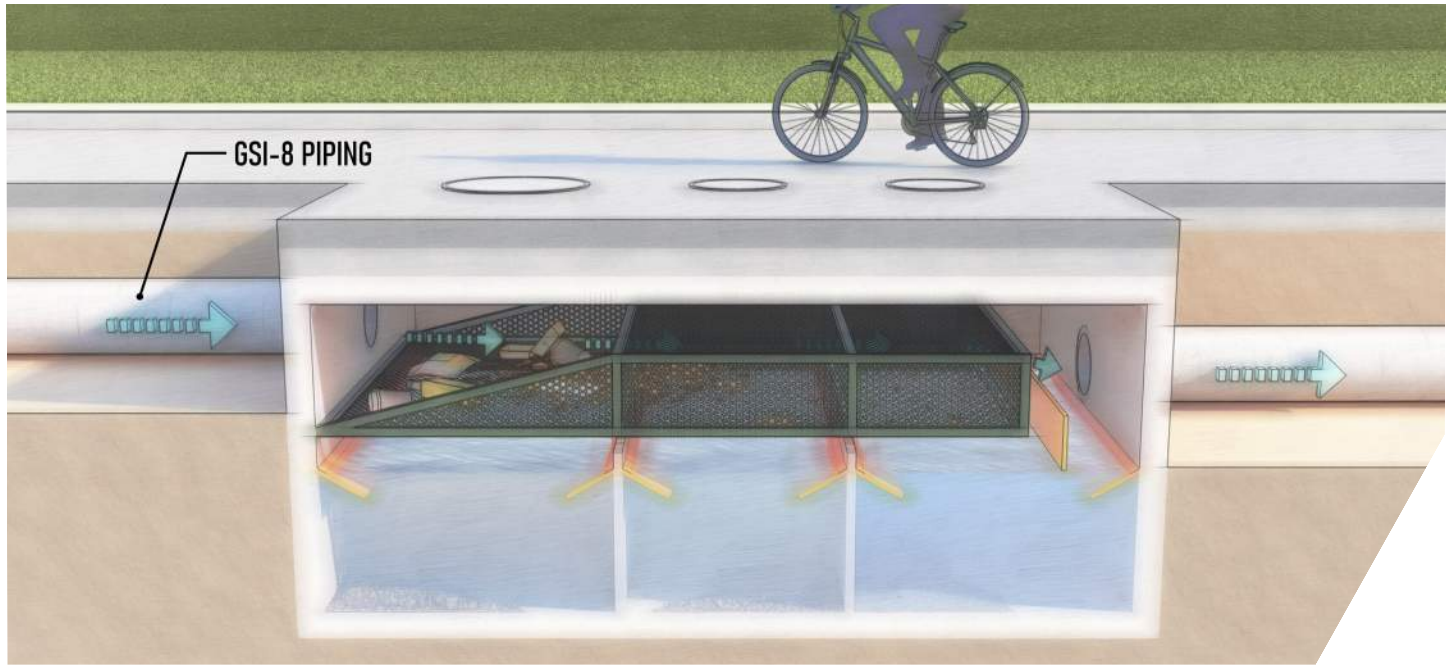
- Provide a sand particle size to treat target pollutant(s).
- Provide the sand filter infiltration rate required and verify with field testing. The infiltration rate must be greater than the design flow rate to the sand filter.
- Provide a bypass for larger flow rates.
- Assess seasonal variations in groundwater table to understand implications for design and function.



2.2 PRETREATMENT (cont.)

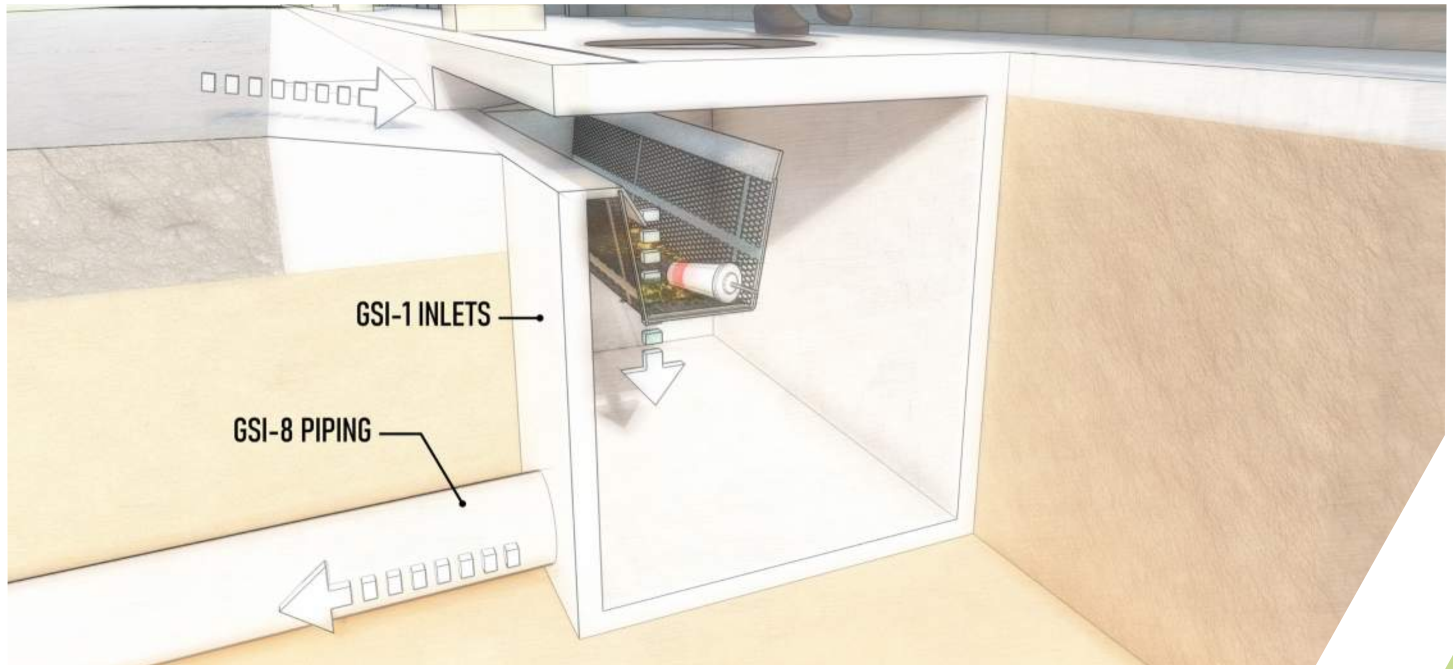
2.2.5 Baffle Box/Grip Separator

Baffle boxes or grit separators are typically proprietary structures that utilize a series of chambers separated by weirs and/or baffles providing for the settling out of sediment and filtration for water quality enhancement. As stormwater enters the baffle box/grit separator, the weirs/baffles slow velocity of the influent stormwater through the chambers allowing suspended solids to settle to the bottom. Floatables rise to the top and may also be captured/collected by a series of weirs/baffles or screens.



2.2.6 Catch Basin Insert

Catch basin inserts are manufactured filters that can be inserted into new or existing inlet structures, providing filtration for water quality enhancement. Filtration occurs when stormwater is collected at the catch basin and is routed through the insert, where debris and sediment are captured within the structure. Some catch basin inserts may be equipped with a special fabric liner to absorb oils as the collected stormwater passes through the insert.

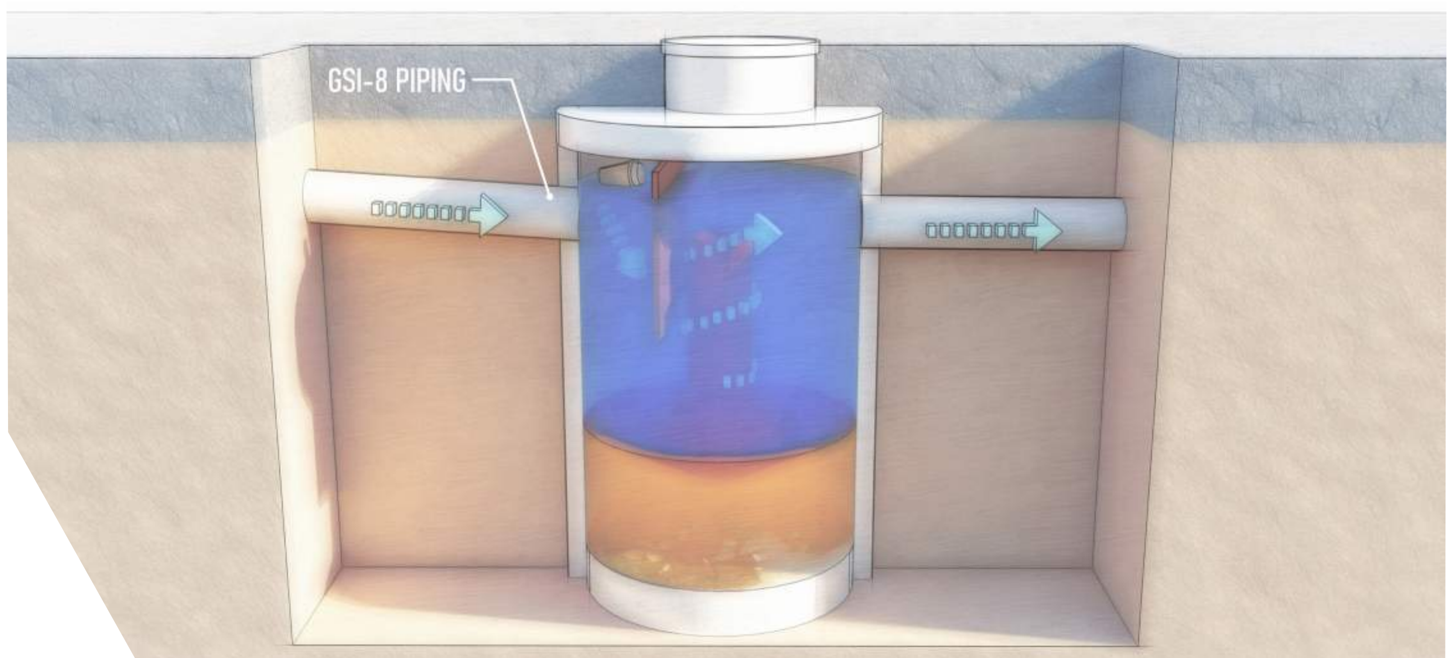


2.2.7 Oil-Water Separator

Oil-water separators are proprietary structures that typically rely on flotation and/or coalescence for water quality enhancement. As stormwater enters the oil-water separator, it may pass through a series of weirs and/or plates that slow velocity of the influent stormwater allowing oil molecules to agglomerate and rise to the surface. The oil is then pumped and/or skimmed off the surface, while effluent stormwater is discharged below the elevation of the oil layer.

2.2.8 Hydrodynamic Separator

Hydrodynamic separators are proprietary flow-through structures that rely on cyclonic separation for water quality enhancement. Stormwater is routed through the hydrodynamic separator through an inflow pipe where the structure configuration encourages settling of particulate matter through centrifugal motion.



2.3 SURFACE WEIRS

Description:

A weir is a device or structure strategically placed to control the flow of stormwater. Weirs can be placed where stormwater discharges into, flows through, or out of a GSI Practice to dissipate energy. Weirs dissipate energy by impeding and impounding flow then forcing it to spill over a notch or opening in the top of the weir. This forces a hydraulic jump and decreases the slope of the hydraulic grade line, thus reducing velocity. When weirs impound water, they also allow for settlement of sediment and pollutants, providing a pretreatment function.

GSI 2.3.1 Concrete Surface Weir:

Utilizes concrete to create the structural wall element of the weir.

GSI 2.3.2 Stacked Stone Surface Weir:

Utilizes stacked ledgestone to create the structural wall element of the weir.

GSI 2.3.3 Manufactured Surface Weir:

Utilizes a manufactured product, such as stop logs, to create the structural wall element of the weir.

Concrete Surface Weir

Stacked Stone Surface Weir

Manufactured Surface Weir

Where to Use:

Surface weirs can be used at inlet points into GSI Practices or within Native Vegetation Swales to reduce the slope of the hydraulic grade line, thus reducing velocity into the GSI.

Surface weirs may also be used as outlet points within GSI Practices to create and regulate water movement between internal pools or cells for GSI Practices in series, including pretreatment forebays and stilling basins for extended wet and dry detention basins. Weirs may also create stepped pools where topography is steep. Surface weirs can be used as overflow weir outlets in the embankment or berm of a GSI Practice that allows water to exit the facility in a controlled manner when the capacity of the facility is exceeded.

Design Considerations:

The following are recommendations and considerations for designing GSI surface weirs. No GSI construction specification for Surface weirs is included in Appendix C. Designer shall provide a detail sheet depicting what shall be constructed. Designer shall also provide technical specifications for construction and material requirements if not covered by standard specifications.

- ➔ Surface weirs shall be sized, configured, and placed to control discharge over the weir and direct it to the desired flow path. Designer shall consider weirs with sharp crests, broad crests, notches, or be of various shapes (e.g. rectangular or trapezoidal) to achieve such design objectives.
- ➔ Surface weirs may be constructed of concrete, stone, or vegetated earthen berms. Designer shall select weir materials based on velocity, shear stresses, and hydrostatic pressure to prevent failure across the full range of anticipated flow conditions, as well as aesthetics and compatibility with the surrounding context.
- ➔ Additional energy dissipation splash pads or stabilization is required on the downstream side of weirs to prevent scour.
- ➔ Earthen surface weirs shall be well vegetated to prevent erosion and failure, and may require additional stabilization.

2.4 LEVEL SPREADERS

Description

A level spreader is a device used in stormwater management systems to evenly distribute and slow down the flow of stormwater runoff over a large area. It is typically made of concrete and is installed at the bottom of a slope or in a channel. The level spreader has a series of weirs or perforations that allow the stormwater to flow out slowly and evenly across the surface, preventing erosion and reducing the amount of sediment and pollutants that are carried downstream.

Where to Use

Use of the level spreader applies only where the spreader can be constructed on undisturbed soil and the area below the level lip is uniform with a slope of 5% or less for the entire length of the facility and is stabilized by natural vegetation (Virginia Department of Environmental Quality 1992).

Design Consideration

The following are recommendations and considerations for designing level spreaders. No GSI construction specification for level spreaders is included in **Appendix H.** Designer shall provide a detail sheet depicting what shall be constructed. Designer shall also provide technical specifications for construction and material requirements if not covered by standard specifications.

Dimensions

- ➔ The width of a level spreader should be at least three times wider than the diameter of the inlet culvert, and the depth should be 9 inches or one-half the culvert diameter, whichever is greater.
- ➔ When discharging into a stream setback with thick ground cover, there must be 13 feet of level spreader for every 1 cubic foot per second (cfs) of flow.
- ➔ When discharging into a setback with forested ground cover, there must be 40 feet of level spreader for every 1 cubic foot per second (cfs) of flow. This design specification is based on maximum flow velocities and is intended to limit erosion in the setback.
- ➔ The minimum level spreader length is 13 feet and the maximum is 130 feet.

Forebay

The first part of the system is the forebay, which is used for the preliminary treatment of stormwater. It is an excavated, bowl-shaped feature that slows the influent stormwater and allows heavy sediment and debris to settle. The forebay may be lined with riprap to reduce erosion within the excavated area. The uneven riprap surfaces function as small sediment traps. When a level spreader is used to disperse outflow from a detention pond, a forebay may be necessary to reduce runoff velocity before the outflow reaches the level spreader.

- ➔ Forebay Sizing: The forebay should be sized so that it is at least 0.2 percent of the contributing catchment's impervious or paved surface area.
- ➔ Forebay Grading: The forebay should slope upward to a depth of 1 foot prior to discharging into the level spreader. Provide a smooth transition grade, less than or equal to 100-year design, for the last 20 feet of the diversion channel entering the level spreader. Grade the level spreader channel to 0% grade. The side slopes of the spreader should be 2H:1V or flatter and should be tied into higher ground to prevent flow around the spreader.

Channel

After the stormwater passes though the forebay, it enters a concrete, rock, or grassed channel—the main body of the level spreader. This is a dead-end channel because it does not directly connect the watershed to the stream. Instead, the channel is a long, shallow impoundment that fills to the level of its lower side. The lower side (the downslope side) of the channel is constructed so that it is level along its full length. This lower side, or level spreader lip, is often constructed of concrete or rock so that it resists erosion. As stormwater enters the channel, it rises until it fills the channel and exits evenly over the lip. The downslope side of the system functions as a long, broad-crested weir.

Level Spreader Lip

- ➔ The Level Spreader lip should be concrete, wood, prefabricated metal, or other durable non-erodible material with a well-anchored footer.
- ➔ Determine the capacity of the spreader by estimating peak flow from the 10-year storm.
- ➔ Restrict the drainage area so that maximum flows into the spreader will not exceed 30 cubic feet per second (cfs).
- ➔ The level spreader lip should be placed 3 to 6 inches above the downstream natural grade elevation to avoid blockage due to turf buildup.

Preserved Areas

After the stormwater passes over the level spreader lip, it enters the preserved area setback, as defined in **Section 5604**. As the stormwater passes through the setback vegetation, some of the water infiltrates.

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5606.3 GSI-3 AREA PROTECTION

Area protection components are physical or visual barriers placed at the edge of the GSI to protect the facility from traffic, pedestrians, and improper maintenance activities. Area protection also increase safety for the public by providing a visual delineation between pedestrian/ vehicular space and the primary GSI Practice. Barriers may also offer an aesthetic benefit by providing a decorative and defined edge to the facility. Area protection shall be used anytime there is a significant change in grade or elevation between the GSI facility and surrounding pedestrian or vehicular area.

DESIGN DELIVERABLE CHECKLIST

- ➔ Plan view of **GSI Practice** indicating location of area protection component(s) including northing/easting points and elevations.
- ➔ Detail/Section view of area protection component(s) specifying recommended product/manufacturer, size, and dimensions (as applicable).

81st & Lydia in Kansas City, MO

Straight Curb

Straight Curb and Gutter

Roll Back Curb and Gutter

Reverse Roll Back Curb and Gutter

Ribbon Curb

3.1 CURBS

Description:

Curb is a reinforced concrete barrier that surrounds the GSI Practice and provides a defined edge to the facility. Curbing can be constructed above grade, serving as a physical vertical barrier, which supports collection and conveyance of stormwater. Curbing can also be flush with the surrounding grade, functioning primarily as a visual barrier and allowing for distributed sheet flow of stormwater into the facility.

GSI 3.1.1 Straight Curb:

A vertical barrier that provides area separation.

GSI 3.1.2 Straight Curb and Gutter:

A vertical barrier that collects and conveys stormwater and directs it to a designated point. This is also commonly known as a “high back” curb.

GSI 3.1.3 Roll Back Curb and Gutter:

A mountable curb that collects and conveys stormwater and directs it to a designated point. This is also commonly known as a “lazy back” curb.

GSI 3.1.4 Reverse Roll Back Curb and Gutter:

Encourages stormwater drainage away from pavements while defining an edge. Reverse roll back curb is geometrically the same as a roll back curb and gutter, but is situated in the opposite direction with the top of curb set flush with the adjoining pavement, and the gutter line sloped away from the pavement and towards the GSI.

GSI 3.1.5 Ribbon Curb:

A curb located flush with adjacent grade that designates a defined edge. Ribbon curb can be used in both pavement and non- pavement applications to create a defined edge.

Where to Use:

Curbing can be applied directly adjacent to roadways or other pavements as well as in vegetated areas. Curbing is traditionally used as part of the roadway cross section to collect and convey stormwater and to promote structural stability of adjoining flexible pavements.

Curbing may also be applied in vegetated areas to define and differentiate maintenance boundaries for the GSI facility and surrounding vegetation. There are five curb types typically used in GSI that can be designed to meet multiple and varying purposes.

Design Considerations:

The following are recommendations and considerations for designing GSI with curb components. Refer to Specification Section 02942 GSI Area protection for construction and material specific requirements.

- ➔ Curbing exceeding 7 inches in height above grade shall be structurally designed and reinforced to withstand expected loading and lateral earth pressures.
- ➔ When curbing is applied in a pedestrian area and extends above the grade of the pavement, a minimum 48-inch clear width in the path of travel must be maintained per US Access Board Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way. 60-inch wide passing spaces must also be provided at maximum intervals of 200 feet.
- ➔ Designer shall consult the approving authority for specifying additional requirements on curb dimensions and reinforcing.

Curb designs outside of the parameters of this guideline shall be submitted for review and approval.

Wood Fencing

Metal Fencing

3.2 FENCING & RAILINGS

Description:

Fencing is a vertical boundary that can delineate GSI extents while providing an aesthetic decorative barrier. Railings provide this same function but are intended for areas where pedestrian safety is a concern, usually due to significant elevation changes. Common fencing and railing types used with GSI include:

- GSI 3.2.1 Wood Fencing
- GSI 3.2.2 Metal Fencing

Where to Use:

Fencing and railings are primarily used within pedestrian walking surfaces to designate GSI boundaries and discourage public access. Fencing or railings shall be used any time the change in grade between the GSI and the adjacent surface exceeds 30 inches, when adjacent slopes exceed 3:1 (horizontal: vertical), or to meet the site specific safety requirements.

Design Considerations:

The following are recommendations and considerations for designing GSI with fencing and/or railing components. Refer to Specification Section 02942 GSI Area protection for construction and material specific requirements.

- Fencing and railings adjacent to roadways shall not infringe on line-of-site requirements. A minimum 2-foot clear zone shall be maintained between the roadway edge and the fence or railing.
- When fencing or railing is applied in a pedestrian area, a minimum 48-inch clear width in the path of travel must be maintained per US Access Board Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way. 60-inch wide passing spaces must also be provided at maximum intervals of 200 feet.
- Fencing and railing shall have a minimum height of 36 inches. When vertical drop between the pedestrian area and the GSI exceeds 30 inches, minimum fencing/railing height shall be 42 inches, or per the requirements of the International Building Code.
- Fencing and railing shall have a minimum clear distance of 1 inch between bottom elevation of bottom rail and top of finished grade beneath the fence. When applied as protection against a significant drop, the bottom rail must be a maximum 15 inches above the ground surface per Public Rights-of-way Accessibility Guidelines.
- Fencing and railing placement shall consider access for maintenance. When the barrier extends around the entire facility, include a gate for access.

Fencing and railing designs outside of the parameters of this guideline shall be submitted for review and approval.

3.3 BOLLARDS

Description:

Bollards provide vertical demarcation to bring attention to the GSI location. Bollards may be metal, wood, or concrete material with a reflector to provide enhanced visibility. Specialty bollards may also be used to incorporate a more artistic element to the area protection design.

- GSI 3.3.1 Wood Bollard
- GSI 3.3.2 Metal Bollard
- GSI 3.3.3 Concrete Bollard
- GSI 3.3.4 Removable Bollard
- GSI 3.3.5 Specialty Bollard

Where to Use:

Bollards shall be used roadside to provide a visual demarcation of the GSI. Bollards may also be used at the entrance to plazas or trails to prevent vehicular traffic from entering the pedestrian areas, or to provide a visual notice in the change of use between two spaces. Removable bollards can be utilized where maintenance access is needed, but other vehicular traffic is not permitted.

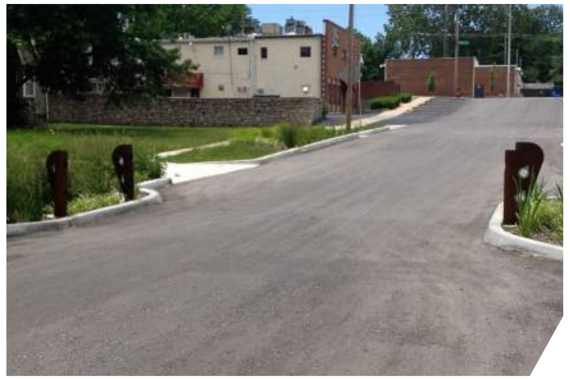
Design Considerations:

The following are recommendations and considerations for designing GSI with bollards. Refer to Specification Section 02942 GSI Area Protection for construction and material specific requirements.

- Bollards adjacent to roadways shall consider line-of-site requirements. A minimum 2-feet clear zone shall be maintained between the roadway edge and the bollard.
- For pedestrian applications of bollards, a minimum 48-inch clear width in the path of travel and between adjacent bollards must be maintained per US Access Board Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way.
- Bollards shall include reflectors to increase visibility.
- Break-away bollards are preferred in the vicinity of vehicular areas for ease of replacement. Bollards in trailhead or maintenance path applications where vehicles will need to access must be removable.

Bollard designs outside of the parameters of this guideline shall be submitted for review and approval.

Specialty Bollard



Metal Bollard

Wood Bollard

Concrete Bollard

Removable Bollard

Stone Boulder

Ledgestone

3.4 STONE BARRIERS

Description:

Stone barriers include both stone boulders and ledgestone walls, both providing a vertical barrier with a more natural edge. Ledgestone can also function as a wall to provide greater flexibility with grade changes.

- GSI 3.4.1 Stone Boulder
- GSI 3.4.2 Ledgestone

Where to Use:

Stone boulders shall be used in areas with large open spaces, such as parks or wide medians, to provide a visual boundary. Stone boulders are not recommended for areas directly adjacent to traffic and shall follow clear zone design requirements in this application. Ledgestone may be used in steeper slope applications to allow for increased changes in grade while providing structural stability for the adjacent slope.

Design Considerations:

The following are recommendations and considerations for designing GSI with stone barriers. Refer to Specification Section 02942 GSI Area Protection for construction and material specific requirements.

- Designer shall specify desired size and spacing of stone boulders. Height and spacing of boulder shall not impede visibility of other GSI aesthetics or maintenance access.
- A minimum of one maintenance access point is required for each GSI site. Spacing of stone boulders shall consider access for maintenance.
  - Where vehicular access is needed between stone boulders, a minimum width of 14 feet shall be maintained between boulders.
  - Where pedestrian access is required between stone boulders, a minimum width of 4 feet shall be maintained between adjacent boulders.
- In retaining wall applications, ledgestone shall be structurally designed to withstand the anticipated loading and provide sufficient reinforcement for adjacent slope. Provisions for drainage shall be provided to relieve hydrostatic pressure buildup behind the wall.

Stone barriers outside of the parameters of this guideline shall be submitted for review and approval.

3.5 CURB GUARDS

Description:

A curb guard is a steel plate that covers an opening in the curb line, providing a consistent curb elevation. A curb guard protects the curb and provides an extension of the vertical barrier.

Where to Use:

A curb guard extends over a curb cut (GSI-1.2) to provide an extension of the curb line.

Design Considerations:

The following are recommendations and considerations for designing GSI with a curb guard. Refer to Specification Section 02942 GSI Area Protection for construction and material specific requirements.

- Designer to specify thickness of curb guard plate based on span of curb opening.
- Manufactured products such as Neenah R-3262 Curb Opening or approved equals may be used in place of a curb guard.

Curb guard designs outside of the parameters of this guideline shall be submitted for review and approval.

Curb Guard

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5606.4 GSI-4 PERMEABLE PAVEMENTS

Permeable pavements are the top layer of the permeable pavement system **GSI Practice**. Permeable pavement allows for infiltration of stormwater through voids or pores in the pavement material. Permeable pavement functions primarily as an inlet, collecting stormwater runoff at the surface and infiltrating into the subsurface storage aggregate media. Use of permeable pavement in place of standard pavement effectively reduces the volume of stormwater runoff by reducing impervious area and infiltrating stormwater at the source.

DESIGN DELIVERABLE CHECKLIST

- ➔ Specify in-situ infiltration testing locations and frequency for all GSI Practices. Reference Specification Section 02956 Green Stormwater Infrastructure In-situ Infiltration Testing for recommended test methodology.
- ➔ Plan view of GSI specifying extents of permeable pavement with northing/easting points, and elevations.
- ➔ Detail/Section view of GSI Practice specifying type of permeable pavement, with type and depth of aggregate media layers, referencing material specifications.
- ➔ Grading plan shall identify **Survey Verification Points** along the boundaries of the permeable pavement and spot elevations within the finished grade of the pavement for contractor verification during construction

Permeable Pavement beneath I-670 Underpass in West Bottoms

Pervious Concrete

4.1 PERVIOUS CONCRETE

Description:

Pervious concrete is a specialty concrete mix consisting of approximately 20 to 25% voids. Pervious concrete functions as the surface material in a permeable pavement GSI allowing water to pass through the voids in the surface as opposed to ponding and running off the pavement. A storage aggregate media layer is located below the pervious concrete, which allows for the temporary storage of stormwater and serves as the structural subbase.

Where to Use:

Pervious concrete can be used in lieu of traditional pavement. It is primarily used in settings with minimal shear stress such as trails, sidewalks, alleyways, parking lots, and parking stalls. Pervious concrete shall not be used in high truck traffic areas, nor in drive lanes where the pervious concrete surface will be exposed to excessive shear stress. The potential for eroding adjacent slopes and other vegetation shall be considered when locating pervious concrete applications. Designer shall confirm with approving authority that use of permeable pavement within the right-of-way is allowed.

Design Considerations:

The following are recommendations and considerations for designing pervious concrete components. Refer to Specification Section 02943 Green Stormwater Infrastructure Pervious Concrete for construction and material specific requirements.

For applications bringing stormwater runoff from upstream drainage area to the pervious concrete, it is recommended that runoff be loaded as distributed sheet flow.

- Pervious concrete may be used in place of a traditional impermeable surface, to reduce impervious area, and therefore reduce stormwater runoff.
- Depth of pervious concrete pavement depends on desired vehicular loading requirements for the application. Designer shall specify pervious concrete pavement depths on the Construction Plans. Recommended pavement depths for pervious concrete applications:
  - Sidewalks = 4 to 5 inches
  - Parking Areas = 6 to 8 inches
- Depth of storage aggregate media depends on designed storage volume for the GSI Practice per GSI-5.3. No. 57 aggregate is recommended directly below the pervious concrete surface.
- Designer shall specify pre- and post-construction infiltration testing per Section 02956 on all permeable pavement applications.

Pervious concrete designs outside of the parameters of this guideline shall be submitted for review and approval.

4.2 POROUS ASPHALT

Description:

According to NAPA guidelines, porous asphalt is a specialized hot mix asphalt consisting of 16 to 22% voids. Porous asphalt allows water to pass through the voids in the asphalt surface as opposed to ponding and running off the pavement surface. A storage aggregate media layer is located below the porous asphalt to stabilize the surface and provide temporary stormwater storage.

Where to Use:

Porous asphalt can be used in lieu of traditional pavement in many applications. It is primarily used in applications with minimal vertical loads and shear stresses such as trails, sidewalks, alleyways, parking lots, and parking stalls. Porous asphalt shall not be used in high truck traffic areas with excessive vertical loads, nor in drive lanes where the porous asphalt surface will be exposed to excessive shear stress. The potential for eroding adjacent slopes and other vegetation shall be considered when locating porous asphalt installations. Porous asphalt is not recommended within the right-of- way.

Design Considerations:

The following are recommendations and considerations for designing porous asphalt components. Refer to Specification Section 02944 Green Stormwater Infrastructure Porous Asphalt for construction and material specific requirements.

- For applications bringing stormwater runoff from upstream drainage area to the porous asphalt, it is recommended that stormwater runoff be loaded as distributed sheet flow.
- Porous asphalt may be used in place of another traditional impermeable surface, to reduce impervious area, and therefore reduce stormwater runoff.
- Depth of porous asphalt pavement depends on desired vehicular loading requirements for the application. Recommended pavement depths for porous asphalt applications typically range from 2 to 5 inches, but may vary based on site specific requirements.
- Depth of storage aggregate media depends on designed volume for the GSI Practice, per GSI-5.3, and structural stability requirements for the pavement. No. 57 aggregate is required immediately below the porous asphalt surface.
- Designer shall specify pre- and post-construction infiltration testing per Section 02956 on all permeable pavement applications.

Porous asphalt designs outside of the parameters of this guideline shall be submitted for review and approval.

Porous Asphalt

Permeable Pavers

Permeable Pavers

4.3 PERMEABLE PAVERS

Description:

Permeable pavers are unit paver systems that allow water to pass through the joints or openings between the individual pavers. Permeable pavers typically incorporate a choker course and a storage aggregate media layer beneath the paver surface that allows for the temporary storage of stormwater. Permeable pavers may also incorporate jointing and bedding material.

Where to Use:

Permeable pavers can be used in lieu of traditional pavement in most applications. Designer shall consult the paver manufacturer for appropriate design loads for the material. The potential for eroding adjacent slopes and other vegetation shall be considered when locating permeable paver installations. Designer shall confirm with approving authority that use of permeable pavement within the right-of-way is allowed.

Design Considerations:

The following are recommendations and considerations for designing permeable paver components. Refer to Specification Section 02945 Green Stormwater Infrastructure Permeable Pavers for construction and material specific requirements.

- ➔ For applications bringing stormwater runoff from upstream areas to the permeable pavers, it is recommended that stormwater runoff be loaded as distributed sheet flow.
- ➔ Permeable pavers may be used in place of another traditional impermeable surface, to reduce impervious area, and therefore reduce stormwater runoff.
- ➔ Depth of permeable paver, choker course, jointing and bedding material, and paver spacing depends on the manufactured paver product. Designer shall specify paver manufacturer or approved equal. When pavers are applied in a pedestrian area, joint spacing shall not exceed 1/2 inch per ADA Standards for Accessible Design.
- ➔ Depth and type of storage aggregate media depends on required storage volume for the GSI Practice, per GSI-5.3.
- ➔ Designer shall specify pre- and post-construction infiltration testing per Section 02956 on all permeable pavement applications.

Permeable paver designs outside of the parameters of this guideline shall be submitted for review and approval.

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5606.5 GSI-5 SOIL & AGGREGATE MEDIA

Soil and aggregate serve as the primary storage and filtration media in a **GSI Practice**. Voids in the media allow for stormwater to move, providing filtration, infiltration and storage functions within the GSI. Storage capacity is primarily recognized in the coarser storage aggregate media materials.

Finer graded media provide a filtration function for the GSI in addition to some storage. Soil media is also designed to support plant growth, which improves infiltration and uptake capacity, as well as overall performance of the GSI.

DESIGN DELIVERABLE CHECKLIST

- ➔ Specify in-situ infiltration testing locations and frequency for all GSI Practices. Reference Specification Section 02956 Green Stormwater Infrastructure In-situ Infiltration Testing for recommended test methodology.
- ➔ Storage capacity calculations including tributary drainage area, impervious tributary area, **required retention volume** (RRV), soil and aggregate component storage volume, and **retention storage volume provided by retention practices** (V_R), including any ponding depth, if applicable.
- ➔ Plan view of GSI Practices specifying extents of grading and GSI media with northing/easting points and elevations.
- ➔ Detail/Section view of GSI Practices specifying depths of each soil and aggregate media layer, referencing material specifications.
- ➔ Grading plan shall identify **Survey Verification Points** along the top and bottom of the side slope, finished surface, and spot elevations of the GSI for contractor verification during construction.

Rachel Morado near Paseo Boulevard

Bioretention Soil Media

Structural Soil Media

Topsoil is the uppermost layer of the soil that contains a majority of the soil's organic matter and microorganisms, making the soil more amenable to sustaining plant life.

Bioretention Soil Media may consist of topsoil, sand, and compost that aids in plant growth and stormwater management. The sand component is preferably part of the topsoil mixture, but at times additional may be included to reach desired infiltration rate. Bioretention soil media promotes infiltration, filters pollutants, and provides an organic, moisture-retentive, and chemically suitable growing media for vegetation.

Amended Native Soil Media consists of native topsoil mixed with compost to serve the same function as bioretention soil media.

Structural Soil is composed of narrowly graded crushed stone mixed with clay loam and hydrogel to provide structural support for pavement systems while promoting infiltration, moisture, and nutrients for plant growth.

Green Roof Media is predominantly composed of lightweight inorganic materials, such as expanded slates, shales or clays; pumice; scoria; or other similar materials. The media must contain no more than 30% organic matter, normally well-aged compost. The percentage of organic matter should be limited, since it can leach nutrients into the runoff from the roof. It is advisable to mix the media in a batch facility prior to delivery to the roof. Manufacturer's specifications should be followed for all proprietary roof systems.

5.1 GROWING MEDIA

Description:

Growing media is a well-mixed blend of soil, organic, and aggregate medias designed to improve soil performance to better suit the application and environment within a GSI Practice.

Where to Use:

Growing media can be used in any GSI Practice intended to promote infiltration, provide stormwater storage and sustain vegetation. Bioretention and amended native soil media are typically used in vegetated GSI. Structural soil media can be used where adjacent pavement requires structural stability, with the intent of promoting vegetation growth. Green roof media is exclusively used in green roofs.

Design Considerations:

The following are recommendations and considerations to be taken when designing growing media. Refer to Specification Section 02947 Green Stormwater Infrastructure Growing Media and Soil Amendments for construction and material specific requirements.

- Bioretention or amended native soil media shall not extend under adjacent paved areas requiring compaction or structural stability, such as curbs, sidewalks or streets. In instances where growing media is desired to extend under pavement, structural soil media or manufactured soil cell products shall be used.
- Depth of growing media depends on application and designed storage volume for the GSI Practice. It is preferred that growing media layer maintain a minimum depth of 30 inches (except for extensive green roofs) to allow for adequate root establishment. Growing media depth shall not exceed 5 feet. GSI Practices with trees must consider additional minimum depth requirements per GSI-7.4 Woody Plants: Trees.
- Recommended porosity assumptions for storage capacity calculations of growing media:
  - Bioretention soil = 0.30
  - Amended native site soils = porosity shall be defined by the designer, based on testing of native site soils
  - Structural soil = 0.40
  - Green roof retention storage is not calculated based on porosity, but on the maximum water retention of the media, which is determined using the methods described by ASTM tests E2397, and E2399, as appropriate.

Growing media designs outside of the parameters of this guideline shall be submitted for review and approval.

5.2 SAND

Sand

Description:

Sand is a fine aggregate that primarily serves to improve infiltration and filtration functions in GSI facilities. Sand media can be applied as the primary GSI media layer, as a media transition layer, or as a constituent in other GSI media mixes.

Where to Use:

Sand is typically found in three primary applications in GSI. Sand can be used in sand filters, as a choker course, and as a constituent of topsoil soil media. The primary function of the sand component in each of these applications is as follows:

- Sand as the primary media in sand filter GSI promotes infiltration and/or filtration.
- Sand as a choker course (GSI-5.4) is a thin layer of sand between GSI media layers that acts as a transition layer between finer and courser media. It is primarily used to prevent migration of finer media to subsurface layers.
- Sand as one of three constituents in topsoil growing media (GSI-5.1), encourages infiltration and storage.

Design Considerations:

The following are recommendations and considerations when designing sand media components. Refer to Specification Section 02946 Green Infrastructure Aggregate Media for construction and material specific requirements.

- Sand shall not extend under adjacent paved areas requiring compaction or structural stability, such as curbs, sidewalks or streets.
- Depth of sand layer depends on application of the media. The following are recommendations for sand media depths and compositions for typical applications:
  - Sand Filters: sand media depth varies per contributing drainage area, plan area of sand filter, and designed storage volume for the GSI Practice. Recommended minimum depth of 18 inches.
  - Choker Course (GSI-5.4): sand media depth for a choker course typically ranges from 3 to 6 inches.
  - Topsoil (GSI-5.1): sand typically is between 35% and 60% of the total mix design.
- Porosity assumption for storage capacity calculations of sand media is 0.30.
- All aggregate shall be clean, double-washed and free of fines as required in the specifications to prevent clogging of the media.

Sand media designs outside of the parameters of this guideline shall be submitted for review and approval.

No. 57 Clean Aggregate

No. 2 Clean Aggregate

5.3 STORAGE AGGREGATE MEDIA

Description:

Storage aggregate media is a coarser graded stone that can be placed in GSI to provide stormwater storage capacity in the void space. Storage aggregate materials include No. 2, No. 3, No. 56, No. 57, and No. 67 aggregate (approximately ¾-inch to 2.5-inch diameter stone).

Where to Use:

Storage aggregate media has a variety of applications in GSI. No. 57 aggregate can be used as the primary storage aggregate layer of the GSI, as well as the bedding for the underdrain or distribution piping (GSI-8) to mitigate clogging of the perforated pipe system. Storage aggregate is also commonly used as the bedding and backfill material for storage chambers (GSI-10) so as not to clog the storage chambers or ability to infiltrate stormwater into underlying soils. No. 2 and No. 3 aggregate is typically used below the primary storage aggregate layer to provide additional stormwater storage.

Design Considerations:

The following are recommendations and considerations to be taken when designing storage aggregate media components. Refer to pecification Section 02946 Green Infrastructure Aggregate Media for construction and material specific requirements.

- ➔ Depth of storage aggregate media depends on application of media. The following are recommendations for aggregate media depths for typical applications:
  - » Storage Aggregate Layer: storage aggregate media depth varies per contributing drainage area, plan area of GSI, and designed storage volume for the GSI Practice.
  - » Aggregate Bedding: aggregate bedding depths for underdrain systems will vary based on diameter of underdrain or distribution piping and configuration within the GSI section. A minimum 4-inch offset from the outside diameter of the pipe is recommended. See GSI-8.1 and GSI 8.2 for pipe bedding design considerations. Aggregate bedding depths for storage chambers will vary based on the type of storage chamber, desired storage volume, and manufacturer requirements (as applicable).
- ➔ Porosity assumption for storage capacity calculations of storage aggregate media is 0.40.
- ➔ All aggregate shall be clean, double-washed and free of fines as required in the specifications to prevent clogging of the media.

Storage aggregate media designs outside of the parameters of this guideline shall be submitted for review and approval.

5.4 CHOKER COURSE

Description:

A choker course is a horizontal transition layer of aggregate media that acts as a media barrier to prevent the migration of finer GSI media layers to the coarser storage aggregate media layers. The choker coarse typically includes sand, No. 7, No. 8, No. 89, or No. 9 aggregates (approximately 1/4-inch to 1.0-inch diameter stone). Sand used as a choker course is the same material as the sand used in bioretention soil media or sand filters (GSI-5.2), though functions as a thin filter layer rather than a constituent of the primary GSI media. No. 57 aggregate as described in GSI-5.3 can also be used as a choker course for permeable pavement systems requiring increased designed structural stability.

Where to Use:

A choker course may be used in a GSI system to control the movement of media between transitioning layers while allowing for stormwater to infiltrate the system.

A choker course is typically used between overlying soil or sand layers and the subsurface coarser storage aggregate media layers. A choker course can also function as jointing or bedding material for permeable pavers (GSI-4.2) and other permeable pavements.

Design Considerations:

The following are recommendations and considerations to be taken when designing storage aggregate media components. Refer to Specification Section 02946 Green Infrastructure Aggregate Media for construction and material specific requirements.

- ➔ Depth of choker course depends on material and the design. The following are recommendations for media depths:
  - » Sand: depth typically ranges from 3 to 6 inches.
  - » No. 7, No. 8, No. 89, and No. 9 Aggregate: depth typically ranges from 3 to 6 inches.
- ➔ Choker course gradation shall consider the gradation of the media layer above and below it. Each successive media layer shall be designed so that the D15 of the larger media is no larger than 5 times the D85 of the smaller media to prevent migration of material from one layer to the other.
- ➔ Porosity assumption for storage capacity calculations of choker course media is 0.30.
- ➔ All aggregate shall be clean, double-washed and free of fines as required in the specifications to prevent clogging of the media.

Choker course designs outside of the parameters of this guideline shall be submitted for review and approval.

Choker Course

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5606.6 GSI-6 MEDIA LINERS

Media liners are synthetic fabric or clay liners used to provide stabilization and/or separation of soil and aggregate media within a **GSI Practice**, and to limit mixing of media layers. Media liners can be permeable or impermeable, to allow or prevent stormwater infiltration, to stabilize media layers, and to protect adjacent infrastructure, as needed.

DESIGN DELIVERABLE CHECKLIST

- ➔ Detail/Section view of GSI: specify media liner type, horizontal and vertical extents within the section, and category/class or manufacturer.
- ➔ Anchoring detail for media liner.

Liner Installation at 81st & Troost

Permeable Geotextile Liner

Permeable Geogrid Liner

6.1 PERMEABLE LINER

Description:

A permeable liner is a non-woven geotextile fabric or a geogrid that allows for the infiltration of stormwater within GSI while providing separation between varying media. Permeable liners may also be used below gravel, mow strips, or other landscaping materials to limit weed growth within the GSI landscaped edging area. In some applications, permeable liners may be used to provide increased structural stability, particularly in pavement applications.

Where to Use:

Permeable liners are used in a variety of GSI to provide support and separation of media layers. Permeable liners are primarily utilized for vertical applications on the sides of the GSI to prevent mixing of surrounding subgrade with GSI media layers. Permeable liners are also sometimes specified for use horizontally in pavement applications, though are not typically Recommended between horizontal media layers due to susceptibility to clogging. When media separation is needed on horizontal applications, a choker course (GSI-5.4) is recommended.

Design Considerations:

The following are recommendations and considerations to be taken when designing GSI with a permeable liner. Refer to Specification Section 02948 Green Stormwater Infrastructure Media Liners for construction and material specific requirements.

- ➔ Designer shall specify required class of media liner meeting the minimum property requirements needed for the given application. Designer may instead specify a preferred manufacturer and product, or approved equal.
- ➔ The following permeable liners are recommended for the given applications:
  - » Vertical media layer separation: minimum of Class 3, Mirafi 140N, or approved equal.
  - » Permeable pavement stabilization: minimum Class 2, Mirafi RS380i, or approved equal.

Permeable liner designs outside of the parameters of this guideline shall be submitted for review and approval.

6.2 IMPERMEABLE LINER

Description:

An impermeable liner is an impermeable membrane, or geomembrane, that prevents water from migrating away from the GSI and repels water with no absorption.

Where to Use:

Impermeable liners shall be used in GSI Practices directly adjacent to traditional pavements and buildings to prevent damage to the infrastructure from infiltrated stormwater migrating from the GSI. Impermeable liners may also be used to limit infiltration for GSI with permanent pools of water. Impervious liners may be required adjacent to roadways; designer shall confirm with approving authority.

Design Considerations:

The following are recommendations and considerations to be taken when designing GSI with an impermeable liner. Refer to Specification Section 02948 Green Stormwater Infrastructure Media Liners for construction and material specific requirements.

- ➔ If the GSI is adjacent to traditional pavement within the public right-of-way or a building, an impermeable liner shall be placed along the side of the GSI adjacent to the pavement or building. The impermeable liner shall extend a minimum depth below the GSI section such that the existing features are not within the infiltration zone of influence. The infiltration zone of influence is defined by the area within a 1:1 (H:V) slope line from the outer edge of the subsurface storage section.
- ➔ Impermeable liners may be synthetic material or compacted soil material meeting minimum permeability and material requirements.

Impermeable liner designs outside of the parameters of this guideline shall be submitted for review and approval.

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5606.7 GSI-7 LANDSCAPING

Landscape plantings are a critical component of several of the GSI practices described in 5605. The GSI landscape must provide the 'curb appeal' for these facilities to be accepted as attractive site amenities. In addition to meeting aesthetic needs the landscape plantings must be durable and functional, as the GSI practices demand the following of the plantings:

- Tolerate varying soil, moisture, and light conditions.
- Anchor the soil and minimize erosion.
- Intercept rainfall and promote infiltration.

A variety of plant types can be successfully used to achieve the functional and aesthetic goals of the various GSI practices. A strong landscape vision and design objectives will inform both the plant selections during design and the choices made in the field during management. Knowing and understanding the cultural needs, growth habits, growth strategies, size, and spread of the plants is valuable information to ensure the landscape plantings are in a position to succeed. The combination of a registered landscape architect who specializes in planting design working with a landscape contractor experienced in GSI installation is necessary for the successful design, implementation, and management of GSI plantings.

This includes understanding the context and conditions of the GSI practice itself and putting plants in a position to compete and succeed. For example, wet detention facilities require plantings which can tolerate frequent periods of inundation and perhaps constant standing water. While a dry detention facility with rapidly draining soil requires planting which can tolerate not just inundation, but also periods of drought.

This section highlights some of these unique challenges associated with GSI landscape plantings, while offering landscape design guidance useful in developing a functional and attractive GSI practice.

Design Deliverable Checklist

- Tree protection plan per the requirements outlined in GSI-7.8.
- Existing tree protection detail GSI-7.8.
- Planting plan per the requirements outlined in GSI-7.10
- Planting details per GSI-7.3, GSI-7.4 and GSI-7.5.
- Temporary irrigation identified for vegetation establishment with watering source, connection, and distribution method identified, along with plans for removal of the temporary irrigation.

Lanscape Installation in Crossroads

7.1 LANDSCAPE DESIGN CONSIDERATIONS

A. GSI Facility Type

The type of GSI facility is a primary consideration for landscape design. Per 5605, "Landscaping" is an important component of the following GSI facilities:

Bioretention (5605.2A)

Since these practices come in a variety of shapes and sizes, the plants utilized may vary from a diverse mix of shrubs and perennials for a bioretention basin to select trees species for engineered tree planters. Bio-swales and rain gardens will need a groundcover layer of vegetation to stabilize soils through all seasons. The designer should consider the size and function of the Bioretention facility along with the anticipated inundation depths and durations when selecting plantings.

Wetland (5605.2D)

These constructed wetlands should include varying depth zones within the permanent pool, including low marsh areas, and high marsh areas, as defined in **Section 5605.2 D**. The varied water depths will support a range of distinct vegetation zones and promote a diverse ecological habitat. High marsh areas may contain shorter wetland perennial species, while low marsh areas support taller emergent plantings such as rushes and sedges. Groupings of trees and shrubs should be considered along the edges of the wetland. The plantings considered for wetlands should include wetland species suited to the designed water depths for the low and high marsh zones, while accounting for stress tolerance to seasonal variation in water availability.

Wet Detention Basin (5605.2E)

These detention basins have a permanent pool of water in dry weather conditions. Recommendations for these facilities include a littoral bench as a planting zone for aquatic vegetation, below the permanent pool surface as defined in **Section 5605.2 E**. The plantings considered for these facilities should include inundation tolerant native vegetation for the littoral zone, while a mix of drought and inundation tolerant native vegetation for the slopes above the littoral zone.

Dry Detention Basin (5605.2F)

These basins are empty under dry-weather conditions and do not maintain a permanent pool. When dry detention basins are also used for retention, they utilize sand-based soils in the basin bottom to promote infiltration and drainage of ponding water, which requires a mix of drought and inundation tolerant native vegetation for the basin bottom and side slopes to handle the fluctuating water levels. This type of facility provides the opportunity for the greatest diversity of vegetation due to the amount of available planting area and the fluctuating water conditions.

B. Native Plants

Utilize native plants as part of the landscape design for GSI facilities provides the following benefits:

Stormwater Functions: Native plants are often well-adapted to the challenging environmental conditions of GSI facilities such as variations in soil type, fluctuations in moisture, and variability in sun and shade. They play an important role in providing stormwater functions like soil stabilization, water filtration, and flood control, which are critical to successful GSI facilities.

Reduced Maintenance: Native plants are generally more durable and require less maintenance than most non-native plants once established. If sited in appropriate growing conditions (right plant / right place), native plants typically require less water, fertilizer, and pesticides potentially reducing long-term costs for maintenance.

Biodiversity: A bonus benefit! While this may not directly support stormwater management goals, native plants provide essential habitat and food sources for local wildlife such as insects, birds, and mammals. Planting native species in GSI facilities will support local ecosystems and contribute to the preservation of biodiversity in our communities.

It is recommended native plants comprise at least 75% of the landscape design for GSI. Native plants should be used across all plant types (trees, shrubs, perennials, etc.) to maximize their benefits.

Soft Rush

Northern Sea Oats

Switchgrass

Switchgrass Monoculture

Layered Planting Approach

Structural Layer

Seasonal Layer

Ground Cover Layer

The following sections describe the components of the layered plantings and offer guidance on developing the GSI planting design. This design approach is adapted from “Planting in a Post-Wild World” by Thomas Rainer and Claudia West. It is a recommended design resource for designers when developing GSI landscapes.

7.1 LANDSCAPE DESIGN CONSIDERATIONS (cont.)

C. Planting Design Approach

Traditional landscape planting design typically prioritizes visual appeal and is not capable of meeting the functional needs or responding to environmental changes associated with GSI facilities. Typically, the goal of the traditional approach is to keep the plants in a static state through activities such as mulching, fertilizing, and pruning. A GSI landscape should be viewed as a dynamic plant community, with the plants allowed to move around, fill in gaps, and respond to environmental changes with the facility. This requires a different landscape design and management approach to address these challenges.

Knowing the plants need to perform and respond, the plantings should be viewed and designed as a **series of vegetative layers** to accommodate both the aesthetic and functional needs of the GSI facility. Key principles and aspects of this layered planting design approach include:

- Avoid using large massings of the same plant or evenly spaced plants with a single growth habit.
- Consider the plantings as groups allowed to intermingle and grow together.
- Utilize groups of plants matched to the conditions of the site and GSI practice.
- Think about the plants vertically/spatially and not just horizontally (plan view) when designing.

A major advantage of this approach is increased plant density, which provides the following benefits:

- More plants to increase both absorption and filtration of stormwater.
- Fewer gaps and bare spots in the plantings, which in turn provide a more attractive landscape appearance.
- Minimizes bare soil to limit the opportunities for weeds to germinate.
- Allows for plant diversity while still providing an attractive and legible landscape.

This approach requires the designer to understand plants beyond their typical size, flower color, or preferred condition and select the plants based on the following criteria:

- Plant types (tree, shrub, grass, etc.)
- Plant sizes (at time of planting and at maturity)
- Plant growth timing (cool season, warm season)
- Plant growth strategy (clump, spreading, seed dispersal)
- Plant life spans
- Functional role of plantings (infiltration, erosion control, etc.)
- Aesthetic role of plantings (plant form, texture, color, etc.)

7.2 EMERGENT PLANTING LAYERS

These are taller/bigger plants which can be typically seen from a distance. These layers provide both visual structure and seasonal interest for the plantings. Two groups of plants make up the emergent layer.

- **Structural or anchor plants** are those with big leaf texture, sturdy stems, and forms that persist through the season. They are generally long-lived plants. Most trees and shrubs would be considered structural plants in the landscape. Clump forming grasses and perennials are preferred herbaceous structural plants.

Structural - Baptisia

Structural - Hollow Joe Pye Weed

Structural - Swamp Milkweed

- **Seasonal plants** are those plants which have floral displays, textural statements, attractive seed heads, or fall color to take the visual lead for certain periods of time. The plants recede into the background once their visual displays diminish. Certain shrubs along with various grasses and perennials would be considered as seasonal plants.

Seasonal - Blazing Star

Seasonal - Blue Mist Flower

Seasonal - Purple Coneflower

Eastern Star Sedge

Gray's Sedge

Path Rush

Purple Love Grass

7.3 GROUNDCOVER PLANTING LAYER

A dense and intermingled layer of spreading and clumping plants (grasses, sedges, and perennials) that will fill in beneath the emergent layers and cover soil. These plants work to minimize weed growth and essentially function as 'living' green mulch, therefore reducing the management need for repeated mulch applications. This layer also serves the critical function of providing erosion control. Groundcover plantings should be able to tolerate shade, as they will be filling in beneath the taller emergent layers. Some of these plants, such as the Roundleaf Groundsel shown below, have clumps of basal foliage/ rosettes, which may stay evergreen and help cover the soil during the winter. Plants selected should have a diversity of root systems from shallow and fibrous to deeper roots to encourage infiltration.

The layered planting approach can include a combination of woody plants and herbaceous plants. The following describes these types of plants and their roles in the layered planting approach.

Roundleaf Groundsel

7.4 WOODY PLANTS: TREES

The use of trees is encouraged, if space allows, as part of a GSI project. Trees primarily serve as structural plantings, providing strong focal points and organizing features in the landscape.

Stormwater Functions:

- Valuable assets that help to collect and store stormwater runoff
- Improve the quality of air, soil, and public health
- Tree canopies intercept rainfall before it reaches the ground while roots absorb water and improve soils to allow for increased infiltration

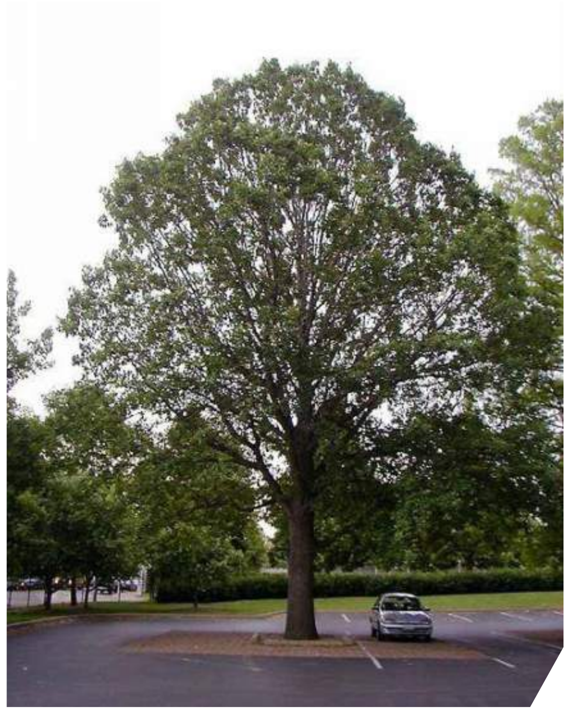
Design Considerations:

Tree selection needs to address the ability of the tree to mature in each microclimate, as well as its ability to meet design objectives. Scale and form are key design considerations. The following are recommendations and consideration to be taken when designing GSI with trees.

- Frame, define, and accentuate spaces
- Focal points in the landscape
- Add human scale
- Provide shade
- Trees planted in City rights-of-way or on City property will need to meet local municipality guidelines.
- Trees should be placed to avoid utility conflicts where possible.
- Trees with deeper roots and smaller trunk flares should be used adjacent to pavements.
- If the GSI asset will experience temporary inundation, select tree species that either withstand or thrive under those conditions.
- Consider the soil volume needed to support healthy root growth based on the estimated mature size of the tree. Although the use of proprietary products like soil cells under sidewalk, parking lots, or roads may add to the initial project costs, the lifetime cost and community benefit is likely to be well worth the initial investment. An alternative to cellular type systems to retain adequate soil volumes is the use of structural soil (GSI-5.1), **Section 5606.5**. To support good tree health a minimum 600 cubic feet of soil for all street trees in the right-of-way should be provided.

Bald Cypress

Swamp White Oak



Gro-Low Shrub

Ninebark

Summersweet Clethra

7.5 WOODY PLANTS: SHRUBS

Shrubs are a key vegetative component for many planting designs. Shrubs can serve as both structural and seasonal plants to set the visual character and help drive the design for the rest of the landscape plan.

Stormwater Functions:

- Play a role in minimizing soil erosion and encouraging stormwater infiltration
- Support phytoremediation – the use of plants to clean, remove and stabilize contaminates in stormwater flows

Design Considerations:

Successful use of shrubs in planting plans is dependent on selecting the correct plant for its location and purpose. The following are recommendations and consideration to be taken when designing GSI with shrubs.

- Distinctive forms of shrubs for visual structure and interest
- Shrub species can be used to provide accent, screening, color, and textural interest in the landscape.
- Add human scale
- Considering a shrub's function can play a key role in creating order in the landscape
- If the shrub will experience temporary inundation, select a species that can either withstand or thrive under those conditions.

7.6 HERBACEOUS PLANTS: GRASSES, PERENNIALS, AND SEDGES

Grasses, perennials, and sedges play a significant role in green stormwater infrastructure vegetation. Larger, upright grasses and perennials can serve as emergent layers (structural and seasonal), while smaller species can be useful as part of the groundcover layer. Sedges are invaluable plants with many species to tolerate a wide range of conditions, from dry to wet and sun to shade. Many sedges are low growing, which makes them essential plants to include as part of the groundcover layer. They help remove pollutants and offer native species that are well adapted to the demands of GSI features.

Stormwater functions:

- Fibrous root systems anchor soil, slow down water flow, and increase infiltration
- Help remove pollutants
- Many native species that are well adapted to the demands of GSI features
- Groundcover plants help cover the ground, minimize erosion, and reduce weed competition

Design Considerations:

Successful use of grass, perennial, and groundcover varieties in the GSI landscape is dependent on selecting the appropriate plant for its location and purpose.

The following are recommendations and consideration to be taken when designing GSI with grasses, perennials and groundcovers.

- Grasses and perennials offer opportunities for diversity, color, and texture.
- Plant species can be used to provide color and textural interest in the landscape.
- When designing with perennials, grasses, and groundcovers consider the plant form in the winter months.
- Plant form is an important factor when selecting perennials. Many large perennial species may become open and leggy at the base and can benefit from small perennials and groundcover plants to define layers in the landscape.
- Integrating these plants with woody shrubs and tree species creates a balanced landscape.
- For grasses, consider how to utilize both cool season and warm season grasses. Cool season grasses green up in early spring and help compete with early weed species, while warm season grasses can offer drought tolerance during the heat of the summer.
- If the plant will experience temporary inundation, select a species that can either withstand or thrive under those conditions.
- Plant material should be installed to provide a minimum one-foot clearance between outer edge of mature plant and pedestrian paths.

Little Bluestem - Grass

Bee Balm - Perennial

Fox Sedge - Sedge

Concrete Edging

Steel & Gravel Edging

7.7 LANDSCAPE EDGING

Landscape edging provides stabilization and defines the limits of a landscape area. Edging creates a tidy appearance to indicate the GSI landscape as an intentional part of the site. It also clearly identifies the limits of the GSI landscape, which requires a different management approach, from areas such as lawn which require maintenance practices such as regular mowing and weeding.

The edging should be used between the landscape plantings and lawn or to separate a transition of loose materials, such as gravel or wood mulch, in a clean fashion. The edging also clearly identifies the limits of where traditional maintenance practices such as mowing and weeding should occur.

The following are recommendations and considerations for designing landscape areas with edging. Refer to 02951 Green Stormwater Infrastructure Plants for construction and material specific requirements.

- ➔ The use of edging can emphasize a planting bed and maintains a clear pathway.
- ➔ Edging should be set firmly in place to prevent settlement of materials.
- ➔ Consider what type of material should be used to coincide with the overall planting design and not be a distraction.

7.8 EXISTING TREE PROTECTION

Description:

Existing trees represent an important asset in the urban forest and should be protected wherever possible. When properly applied, protection measures minimize the negative effects of construction work and disturbance on trees.

Where to Use:

Tree protection measures should be used around trees that are to receive credit with retention value reduction and remain in place after construction. The designer should prepare a Tree Protection Plan that annotates all existing trees surveyed and identifies the necessary tree protection measures required during the construction process.

Considerations:

The following are recommendations and considerations for preparing the Tree Protection Plan. Refer to Specification Section 02949 Green Stormwater Infrastructure Existing Tree Protection for construction and material specific requirements.

- ➔ All existing trees within the project extents should be surveyed including northing, easting, and diameter breast height (DBH).
- ➔ Assess surveyed trees and provide tree species, size (DBH and tree canopy diameter), overall health, and location documented. A tree protection plan should identify if existing trees should be protected or removed.
- ➔ For public projects, designer should work with the local jurisdiction during the design process to identify opportunities to incorporate required tree replacements into the overall landscape plan.
- ➔ Consider impact to existing trees when developing grading plan. Any improvements that require digging, excavating, trenching,changing of grade, or other actions within the tree protection zone should be avoided, if possible. Alternative methods to trenching, such as boring, should be considered to avoid damage to existing trees. If improvements are required within a tree protection zone, specify removal and replacement of the existing tree.

Existing Tree Protection

The minimum size of plants at time of planting shall be as noted below, or per the landscape requirements of the approving jurisdiction in which the GSI facility resides.

Emergent Layers

- Structural
  - Shade Trees (2" caliper)
  - Ornamental Trees (1.5" caliper)
  - Evergreen Trees (6' ht.)
  - Multi-Stem Shade or Ornamental Trees (7'-8' ht.)
  - Shrubs (#3/#5 cont.)
  - Perennials & Grasses (#1 cont.)
- Seasonal
  - Shrubs (#3/#5 cont.)
  - Perennials & Grasses (#1 cont.)

Groundcover Layer:

- Grasses & Sedges (quart size for deeper basins or plug size in shallow basins)
- Perennials (quart size for deeper basins or plug size in shallow basins)

7.9 DESIGN CRITERIA & PERFORMANCE REQUIREMENTS

It is recommended the layered planting approach shall generally break down as follows:

- 10-15% Structural Plantings (Trees, shrubs, large grasses and perennials)
- 30-40% Seasonal plantings (Shrubs, mid-height grasses and perennials)
- 40-50% Groundcover plantings (Low-growing grasses, sedges, and perennials)

Additional design criteria include:

- Achieve an average plant density of 12-inches on center at time of planting.
- Use native plants for at least 75% of the overall landscape design.
- Use a mix of grasses, sedges, and perennials. (60% grasses/sedges and 40% perennials).
- Use both cool-season and warm-season grasses.
- Balance diversity by not using more than 25% of a single species on the project planting plan.
- Trees and shrubs (woody plant materials) may not be appropriate for in bottom of GSI practices with underdrain systems.

Utilizing plug-sized plants for the Groundcover Layer can be an affordable planting approach to achieve the recommended plant density noted in the design criteria above. However, there are circumstances in which larger plant sizes should be considered for the groundcover layer plantings:

- For GSI facilities which may have ponding depths greater than 12 inches. Larger storm events may carry sediment to these facilities which can be deposited onto the foliage of smaller plug sized plants as the water drains. This sediment can be detrimental to plant function and initial establishment.
- For GSI facilities which may have a Fall planting timeline. Fall is an ideal planting season, but if the planting schedule is anticipated to extend into late October (near the first frost date), then quart-sized plants may be more appropriate. Plug-sized plantings installed late in the Fall do not have time to establish their roots. This coupled with their small root mass means plugs are susceptible to being 'popped-out' of the soil during periods of cold temperatures due to freeze and thaw, which affects the survivability of the plants.

7.10 PLANTING PLAN

Description

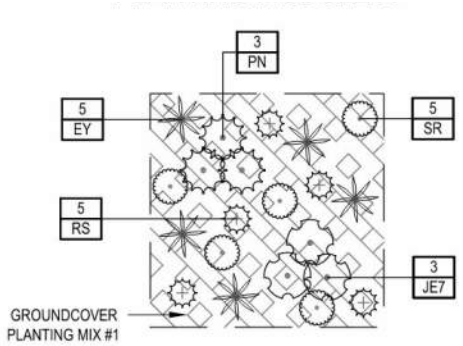
Planting plans accompanied by the appropriate specifications provide the detail needed to install the vegetation within a GSI facility. The intent of the planting plan is to provide clear and consistent directions to the contractor.

Planting Plan Requirements

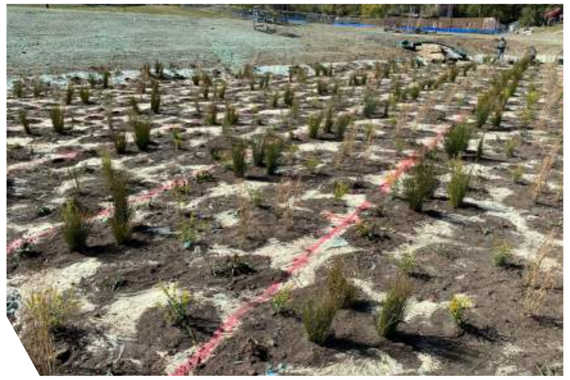
- General
  - North arrow, scale, legend and sealed by a registered landscape architect in the State of Kansas or Missouri.
- Existing Conditions
  - Existing grade information, including labeled contours.
  - Location, size (shown as DBH), and common name of all existing trees. Clearly indicate those trees to be protected (GSI-7.1) and those existing trees to be removed as part of the project.
  - Location, size, and type of all above-ground and underground utilities and structures within landscaping extents. Include proper notation, where appropriate, as to any safety hazards to avoid during installation of landscaping.
  - Identification of all hardscape elements, including but not limited to above grade barriers (GSI-3), street, sidewalks or other pedestrian areas within the vicinity of the landscaping extents.
- Proposed Conditions
  - Location of all materials including but not limited to above grade barriers (GSI-3), plants, landscape edging, light fixtures (pole mounted, wall mounted, and ground mounted), hardscape features, and plant installation details.
  - Plant materials labeled using plant code and legend with quantity of plant type. Plant symbols should be shown at 3/4 mature size when individual symbols are used. Groups of shrubs or smaller plants may be shown as hatched areas where appropriate.
  - Finished grade information including labeled contours and spot elevations. Slope protection boundaries of erosion control blanket or other erosion prevention measures needed during plant establishment.
  - Plant schedule in table format including type of vegetation (tree, shrub, grass, perennial, groundcover), plant code, quantity, botanical and common names, size and spacing.

7.10 PLANTING PLAN (cont.)

Modular/Template Approach



Grid Layout On-Site



For smaller GSI facilities, a planting plan which indicates all plantings through plant symbols may be the preferred method for documenting the design.

For large GSI facilities, consider using a modular or planting template approach to make the planting plan documentation efficient to produce and layout clear to the installer. This approach assumes a standard planting template size, such as 10' x 10', that can be repeated consistently by the installer in the field to achieve the intended design intent. The template size selected will depend on the design and scale of the planting area. This allows the installer to mark a grid layout in the field across the planting area and then proceed with installation of the planting layers by using the template to place the plants. The designer should include notes on the drawings for sequence of plantings. Typically, the larger structural plants should be installed first and followed by the seasonal plantings. The groundcover layer should be the last to be installed as these plants will fill in and around the other plants.

This approach to design and installation can create recognizable patterns, making the GSI landscape appear legible and intentional. For those larger GSI facilities which may require more variation as part of the landscape design, the designer may choose to develop more detailed landscape plans to document the specific design choices and intent.

5606.8 GSI-8 PIPING

Description:

GSI piping consists of all piping and appurtenances within a **GSI Practice**. Piping is primarily intended to convey stormwater to or away from the GSI Practice and to provide access or observation to the subsurface of the GSI. Piping is also used to protect utilities within the footprint of the GSI from water damage when these utilities cannot be relocated, as well as to protect the GSI itself from contamination from the utility.

DESIGN DELIVERABLE CHECKLIST

- Specify in-situ infiltration testing locations and frequency for all GSI Practices. Reference Specification Section 02956 Green Stormwater Infrastructure In-situ Infiltration Testing for recommended test methodology.
- Plan view of GSI Practice indicating location of all piping components including northing/easting, invert elevations , and stationing (as applicable).
- Profile view of pipe lengths, size, material, and installed surface and invert elevations (as applicable).
- Pipe capacity, design flow rates, maximum velocity calculations, and hydraulic grade line elevations (as applicable).
- Detail of anchoring design to prevent flotation (as applicable).
- Detail of connection to GSI outlet or downstream drainage system (as applicable).

Roadside Bioretention on 74th Street

PVC Underdrain Pipe

HDPE Underdrain Pipe

8.1 UNDERDRAIN

Description:

An underdrain is a perforated plastic pipe, usually polyvinyl chloride (PVC) or high-density polyethylene (HDPE), that conveys stormwater from the subsurface of the GSI facility. While typically perforated or slotted, portions of the underdrain can be designed as solid pipe when needed, with applicable fittings. An underdrain provides for dewatering of the GSI storage areas while still allowing for infiltration into the existing subgrade.

Where to Use:

An underdrain shall be used in GSI sites with limited infiltration capacity that require dewatering of subsurface media. An underdrain shall be installed in the storage aggregate media (GSI-5.3) of the GSI.

Design Considerations:

The following are recommendations and considerations to be taken when designing an underdrain system. Refer to Specification Section 02954 Green Stormwater Infrastructure Piping for construction and material specific requirements.

- Underdrain shall be no less than 6 inches in diameter for maintenance considerations. Underdrain material shall be specified considering loading requirements based on application and location.
- Underdrain shall be sized to dewater the GSI within the specified drawdown time for the GSI practice defined in **Section 5605**:
  - Determine the design head on the orifice at or near the outfall (h_o), equal to one half of the sum of the media depth above the orifice (d_m) and the maximum ponding depth in the facility (h_{max}).

Equation 5606-1:

$$h_0 = \frac{1}{2} \sum d_m + h_{max}$$

h_o = Design head above underdrain (ft)

d_m = Depth of media layer(s) above underdrain (ft

h_{max} = Maximum ponding depth (ft)

  - Determine the average rate of flow to drain the required retention volume (RRV) within the specified drawdown time:

Equation 5606-2:

$$Q_{avg} = \frac{RRV}{t_{max}}$$

Q_{avg} = Average rate of flow to the underdrain (cfs)

RRV = Required retention volume tributary to the GSI (ft^3)

t_{max} = Maximum drawdown time (seconds)

  - Determine the underdrain area required to drain the average flow rate using the orifice equation:

Equation 5606-3:

$$Q_{avg} = 0.6 * A \sqrt{2 * g * h_o}$$

Q_{avg} = Average rate of flow to the underdrain (cfs)

0.6 = Discharge coefficient

A = Cross-sectional area of underdrain (ft^2)

g = Acceleration of gravity, 32.2 ft/s^2

h_o = Design head above underdrain (ft)

  - Storage aggregate media for underdrain bedding shall extend a minimum of 4 inches beyond the outside diameter of the underdrain. No. 57 aggregate per GSI-5.3 (**Section 5606.3**) is recommended for bedding aggregate material. At a minimum, storage aggregate media D50 gradation shall be larger than the perforation diameter specified.
  - It is recommended that underdrain be designed with an adjustable flow control mechanism at the downstream end prior to discharging from the GSI practice, such as a valve, upturned elbow, or manufactured outlet control structure with inline weir (GSI-9.2, **Section 5606.9**). Flow control mechanisms maximize GSI storage and infiltration capacity.
  - For portions of the underdrain that are not perforated, anti-flotation design shall be considered.

Underdrain designs outside of the parameters of this guideline shall be submitted for review and approval.

Distribution Pipe

8.2 DISTRIBUTION PIPE

Description:

A distribution pipe is a perforated plastic pipe, usually polyvinyl chloride (PVC) or high-density polyethylene (HDPE), that conveys stormwater from an upstream collection point into the subsurface of the GSI. While typically perforated, portions of the distribution pipe can be design as solid pipe when needed, with applicable fittings. A distribution pipe allows for introduction of stormwater to the subsurface of the GSI when existing site and infrastructure elevations prevent introducing stormwater flows at the surface of the GSI. The perforated pipe distributes stormwater through the subsurface of the GSI.

Where to Use:

A distribution pipe can be used in GSI applications where stormwater cannot be introduced at the surface of the GSI due to grade restrictions or other constraints. A distribution pipe is commonly used to convey stormwater from an inlet or storm sewer system, where depth is constrained, and discharge below grade is necessary.

Design Considerations:

The following are recommendations and considerations to be taken when designing a distribution pipe. Refer to Specification Section 02954 Green Stormwater Infrastructure Piping for construction and material specific requirements.

- For upstream routing of storm piping to the GSI, the following shall be considered:
    - Confirm ponding depth does not cause backups into the connecting storm sewer
    - Confirm adequate pipe slope is provided for positive drainage to the distribution pipe
    - Confirm adequate cover is provided for the pipe material used to address freezing concerns as well as vehicle traffic loading, as applicable.
- Storage aggregate media for distribution pipe bedding shall extend a minimum of 4 inches beyond the outside diameter of the underdrain. No. 57 aggregate per GSI-5.3 is recommended for bedding aggregate material. At a minimum, storage aggregate minimum gradation sieve shall be larger than the perforation diameter specified.
- Distribution pipe is recommended to be no less than 6 inches in diameter for maintenance considerations. Distribution pipe material shall be specified considering loading requirements based on application, depth and location.
- Total calculated outflow through distribution pipe perforations shall exceed the designed inflow to the GSI. The capacity of the upstream inlet shall be considered, to prevent hydraulic backup of the connected upstream system for the design flow. Use of distribution piping shall consider the upstream head on the pipe. Designer shall provide hydraulic grade line elevations for the design flow and up to the capacity of the upstream contributing system.
- Distribution piping shall extend through the length of the GSI facility and have a minimal slope toward the GSI. Designer shall consider perpendicular extensions off the primary distribution pipe to adequately distribute flow within the subsurface of the GSI when appropriate
- Distribution piping is most appropriate for infiltration practices. If Distribution pipe is used in GSI practices that include underdrains, the distribution piping shall be elevated above the growing media such that the stormwater cannot bypass the filter media.
- For portions of the distribution pipe that are not perforated, anti-flotation design shall be considered, when appropriate.

Distribution pipe designs outside of the parameters of this guideline shall be submitted for review and approval.

8.3 CLEANOUT

Cleanout in Soil

Cleanout in Pavement

Description:

A cleanout is a plastic vertical piping application, usually polyvinyl chloride (PVC) or high-density polyethylene (HDPE), or manufactured structure that extends from the surface of a GSI facility and connects to the underdrain or distribution pipe to provide inspection and maintenance access.

Where to Use:

A cleanout shall be used with all underdrain (GSI-8.1) and distribution pipe (GSI-8.2) components. A cleanout shall be located at the upstream end of all subsurface piping, at junctions or bends, or intermittently to provide access at a maximum spacing interval of 100 feet.

Design Considerations:

The following are recommendations and considerations to be taken when designing a cleanout. Refer to Specification Section 02954 Green Stormwater Infrastructure Piping for construction and material specific requirements.

- Cleanout shall be no less than 6 inches in diameter. Cleanout diameter shall be as large as the diameter of the subsurface pipe it is accessing, at a minimum.
- Cleanout in pavement applications shall be flush with adjacent grade to prevent trip hazards, with a HS-25 traffic-rated frame and cover, such as Neenah R-1976 product or similar.
- Cleanout in soil shall extend above finished grade to remain accessible over time. Cleanout RIM shall be at or above the designed ponding elevation to avoid short-circuiting of the soil and aggregate media layers. Height of cleanout above finished grade shall consider aesthetic visibility of piping component. It is recommended that exposed pipe be black in color or consider specifying decorative rock around the exposed pipe.
- Cleanout may consist of a manufactured structure, or, two 45□ elbow fittings connected to subsurface piping. Two 45□ elbow fittings may be replaced with 90□ elbow or tee fitting when constrained by depth. Designer shall verify installed height of specified fitting(s) fits within depth from cleanout rim to underdrain invert elevation.
- Anchoring of the cleanout shall be provided to prevent flotation, as appropriate.
- Manufactured structures with solid lids may be used for cleanouts instead of individual piping components.

Cleanout designs outside of the parameters of this guideline shall be submitted for review and approval.

Observation Well

Observation Well

8.4 OBSERVATION WELL

Description:

An observation well is a vertical application of slotted well screen that penetrates the GSI media layers, allowing viewing and measurement of the water elevation in the GSI subsurface. Measuring the drawdown of water levels in the GSI facility monitors the overall function of the GSI.

Where to Use:

Observation wells can be used in GSI with a storage aggregate media (GSI-5.3) storage lay layer where monitoring is desired or required. Observation wells are recommended for all GSI practices relying solely on infiltration to provide inspection access to confirm the function of the subsurface drainage layers.

Design Considerations:

The following are recommendations and considerations to be taken when designing an observation well. Refer to Specification Section 02954 Green Stormwater Infrastructure Piping for construction and material specific requirements.

- Observation well diameter shall consider proposed data monitoring equipment to be installed. Observation wells shall not be smaller than 2" in diameter for ease of access.
- Slotted portion of the observation well shall be located within aggregate media of the GSI to prevent clogging of the observation well.
- Observation well in pavement applications shall be flush with adjacent grade with a traffic-rated frame and cover, such as Neenah R-1976 product or approved equal.
- Cleanout RIM shall be at or above the designed ponding elevation to avoid short-circuiting of the soil and aggregate media layers.
- Designer shall consider aesthetics of the portion of the pipe that is exposed above grade. It is recommended that exposed pipe be black in color or consider specifying decorative rock around the exposed pipe.

Observation well designs outside of the parameters of this guideline shall be submitted for review and approval.

8.5 ANTI-SEEP COLLAR

Description:

An anti-seep collar reduces the preferential flow of stormwater from GSI to adjacent subgrade or laterally along a pipe and/or utility. An anti-seep collar generally consists of a plastic or bentonite aggregate collar with sealant around the outside diameter of a pipe and/or utility.

- **GSI 8.5.1 HDPE Anti-Seep Collar**
- **GSI 8.5.2 Bentonite Aggregate Anti-Seep Collar**

Where to Use:

An anti-seep collar is installed at either end of a utility sleeve (GSI-8.6) or at the edge of the GSI where an impermeable barrier is used to reduce a lateral flow from the extents of GSI facility. Anti-seep collars shall be considered in urban areas or where GSI is directly adjacent to buildings or utility corridors. Consider placing outside of the GSI footprint itself so as not to contaminate the media.

Design Considerations:

The following are recommendations and considerations to be taken when designing an anti-seep collar. Refer to Specification Section 02954 Green Stormwater Infrastructure Piping for construction and material specific requirements.

- The anti-seep collar shall extend at a minimum beyond the extents of the aggregate bedding material. HDPE anti-seep collar shall be a minimum of 3 times the diameter of the utility service, utility sleeve, or pipe around which the anti-seep collar is installed. Bentonite aggregate anti-seep collar may extend a minimum of 1' into the undisturbed soil material on the sides and bottom of the trench.
- Designer shall consult the utility owner for protection requirements of utility within the vicinity of stormwater infrastructure. Relocation of the utility outside the extents of the GSI facility is preferred.
- The recommended thickness for bentonite aggregate anti-seep collar is as follows:
  - Pipe outside diameter <= 6" : 0.5'
  - 6" < Pipe outside diameter <= 36" : 1.0'
  - 36" < Pipe outside diameter <= 66" : 1.5'
  - Pipe outside diameter > 66": 2.0'

Anti-seep collar designs outside of the parameters of this guideline shall be submitted for review and approval.

8.6 UTILITY SLEEVE

Description:

A utility sleeve protects a utility service or pipe from stormwater infiltration when relocation of the utility or pipe is not viable. A utility sleeve also protects the GSI facility from the utility service or pipe.

Where to Use:

A utility sleeve may be installed on a utility service or pipe that passes through, under, or adjacent to a GSI installation. Utility sleeves are also used in pipe crossing or utility crossing situations to prevent cross-contamination.

Design Considerations:

The following are recommendations and considerations to be taken when designing a utility sleeve. Refer to Specification Section 02954 Green Stormwater Infrastructure Piping for construction and material specific requirements.

- ➔ A utility service and/or pipe shall be relocated outside the extents of the GSI installation, when possible.
- ➔ Designer shall consult the utility owner for protection requirements of utility within the extents and/or vicinity of stormwater infrastructure.
- ➔ Anti-seep collar shall be installed at either end of a utility sleeve.

A utility sleeve design outside of the parameters of this guideline shall be submitted for review and approval.

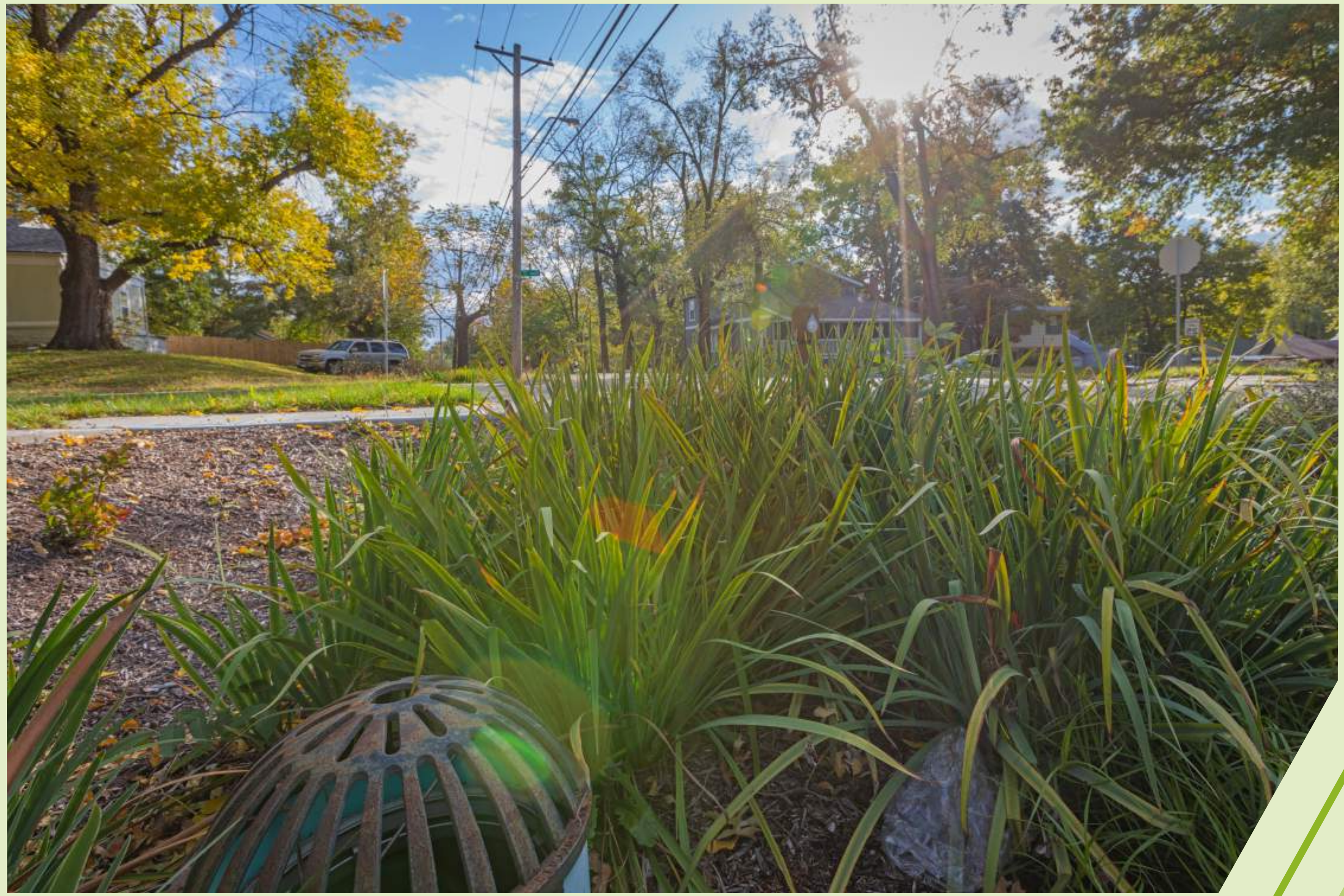
5606.9 GSI-9 OUTLETS

GSI outlets are designed to allow excess stormwater flows to exit the GSI when the capacity of the facility is exceeded. The outlet structure can be designed to control water levels both at the surface and in the subsurface of the **GSI Practice**. Stormwater above the finished grade of the GSI is controlled with an overflow outlet or a weir that is overtopped once the ponding elevation in the facility is exceeded. Outlets can be designed with addition flow control mechanisms to control outflow from the storage aggregate media or underdrain components, to maximize the storage capacity of the GSI.

DESIGN DELIVERABLE CHECKLIST

- ➔ Plan view of GSI Practice indicating location of outlet structure(s) including northing/easting points and RIM elevations.
- ➔ Spot elevations to show positive drainage path towards the outlet structure(s) as well as major overland flow paths and bypass for storm events that exceed the design capacity of the GSI Practice.
- ➔ Detail/Section view of outlet structure (s) specifying recommended product/manufacturer, structure size, dimensions, and elevations of overflow mechanisms including structure top, flow control weir/orifice/ valve, and inverts (as applicable).
- ➔ Detail of anchoring design to prevent flotation (as applicable).
- ➔ Maximum outflow rate and drawdown time calculations.
- ➔ Detail of outlet structure connection to downstream drainage system.

Overflow Riser in Raingarden Bed



Manufactured Overflow Riser

Manufactured Overflow Riser

9.1 OVERFLOW OUTLET

Description:

An overflow outlet allows for stormwater to overflow from the GSI bypassing the subsurface media. Overflow outlets can consist of solid plastic pipe and fittings, a manufactured structure with a grated cover, or an overflow weir that extends above the finished grade of the GSI to collect stormwater from the GSI surface. When the design ponding elevation in the facility is exceeded, the outlet conveys flows away from the GSI to a downstream conveyance system. Overflow outlets typically consist of the following types:

GSI 9.1.1 Overflow Riser:

Consists of a solid plastic pipe, usually polyvinyl chloride (PVC) or high-density polyethylene (HDPE) with a domed or flat grated top.

GSI 9.1.2 Manufactured Overflow Riser:

Consists of prefabricated outlet structure, it should be noted that manufactured outlets are often referred to by the manufacturer as "inlets" due to their stormwater collection function

GSI 9.1.3 Overflow Surface Weir:

Can consist of soil, stacked stone, concrete, or manufactured weirs located along the embankment or berm of a GSI Practice. Surface weirs are discussed further in GSI-2.3.

Where to Use:

Overflow outlets shall be used in GSI applications with the potential for stormwater inflow greater than the design capacity and ponded elevation shall be controlled to prevent flooding of adjacent areas, such as GSI adjacent to private property, buildings, or streets. Overflow outlets are most commonly used to control the ponded water surface elevation within the GSI facility.

Design Considerations:

The following are recommendations and considerations to be taken when designing overflow outlets. Refer to Specification Section 02955 Green Stormwater Infrastructure Outlets for construction and material requirements.

- At least 1" of freeboard shall be provided above the outlet elevation. If storms larger than the RRV are routed through the GSI, the water surface elevation above the outlet shall be determined, and at least 1" of freeboard above that elevation must be provided. The 10-year design storm shall either bypass the GSI, or pass through the designated outlet(s), including an overflow weir or spillway, without overtopping the basin.
- Overflow elevations shall be set at the design ponding height. Ponding volume above the overflow elevation is not recognized as storage volume in the GSI, as it is assumed to discharge through the outlet and bypass the facility.
- Designer is required to evaluate the impact of the outflow from the GSI to the downstream drainage system by providing existing and proposed hydraulic grade line elevations.

9.1 OVERFLOW OUTLET (cont.)

Overflow Risers (GSI-9.1.1)

- Overflow risers may consist of a manufactured structure, or, two 45° elbow fittings to connect to outlet piping, when feasible. Two 45° elbow fittings may be replaced with a 90° elbow or tee fitting when constrained by depth.
- Manufactured overflow riser standard detail is often provided by the manufacturer. Designer shall review detail and provide additional information as needed to define water level control function of the GSI facility.
- Designer shall consider aesthetics of the portion of the pipe that is exposed above grade. It is recommended that exposed pipe be black in color or consider specifying decorative rock around the exposed pipe.
- Designer shall provide an anchoring design for the overflow riser to mitigate flotation of the structure, as needed.
- Designer shall consider specifying a catch basket or strainer product within in the outlet structure to minimize debris exiting the facility.
- Designer shall take measures to minimize standing water in structure sumps to mitigate mosquito habitat.

Overflow Surface Weirs (GSI-9.1.3)

- Surface weirs shall be sized, configured, and placed to control discharge over the weir and direct it to the desired flow path. Designer shall consider weirs with sharp crests, broad crests, notches, or be of various shapes (e.g. rectangular or trapezoidal) to achieve such design objectives.
- Surface weirs may be constructed of concrete, stone, or vegetated earthen berms. Designer shall select weir materials based on velocity, shear stresses, and hydrostatic pressure to prevent failure across the full range of anticipated flow conditions, as well as aesthetics and compatibility with the surrounding context.
- Additional energy dissipation (GSI-2, **Section 5606.2**) or stabilization is required on the downstream side of weirs to prevent scour.
- Earthen surface weirs shall be well vegetated to prevent erosion and failure, and may require additional stabilization.

Overflow outlet designs outside of the parameters of this guideline shall be submitted for review and approval.

Overflow Surface Weir

Weir Control Structure

Outlet Control Structure

Continuous Monitoring and Adaptive Controls

9.2 OUTLET CONTROL STRUCTURE

Description:

Outlet control structures include overflow risers with internal control mechanisms, such as weirs, valves, or orifices, that provide controlled release of stormwater flows from both the surface and the subsurface of the GSI. Manufactured outlet control structures are pre- fabricated control structures that can be designed with internal water level and outflow control features.

GSI 9.2.1 Weir Control Structure:

Consists of a structure that utilizes internal weirs or stop logs to control water surface elevations within the subsurface of the GSI.

GSI 9.2.2 Valve Control Structure:

Consists of a structure with an internal valve, such as a gate or butterfly valve, to control outflow rates from the GSI.

GSI 9.2.3 Standpipe Control Structure:

Consists of a structure with an internal vertical pipe connected to the outflow pipe from the facility that controls the water surface elevation within the subsurface of the GSI.

GSI 9.2.4 Continuous Monitoring and Adaptive Controls (CMAC):

Consists of a system where sensors constantly monitor precipitation forecasts and GSI practice water levels and use the information to adjust water outflow via automated valves to optimize GSI performance. They are most commonly used to improve water quality in detention GSI practices. CMAC technology is designed to detain larger storms, particularly the 2-year storm longer than they otherwise would be detained with a passive control structure. If CMAC technology is used to optimize storage and function of the GSI practice, the CMAC-controlled volume between the permanent pool and the secondary outlet control structure may be factored into the storage volume provided by the retention practice.

Where to Use:

Outlet control structures shall be used in GSI outlet applications with below- or above- grade storage to maximize storage and infiltration capacity by controlling the water level in both the surface and subsurface of the facility.

9.2 OUTLET CONTROL STRUCTURE (cont.)

Design Considerations:

The following are recommendations and considerations to be taken when designing outlet control structures. Refer to Specification Section 02955 Green Stormwater Infrastructure Outlets for construction and material specific requirements.

- Outlet control structures shall be sized to dewater the GSI within the specified drawdown time for the GSI practice defined in **Section 5605**.
- If GSI is designed to meet retention and detention requirements, then:
  - **Primary control structure**: shall be designed to control the 2-year design storm.
  - **Secondary control structure**: shall be designed to control the 10-year and up to the 100-year design storms
  - **Overflow spillway**: shall be sized to safely pass rainfall events larger than the design capacity of the GSI. The 100-year design storm may pass through the overflow spillway provided the release rates meet requirements specified in Table 5602-7 (**Section 5602.3 C**)
- If GSI is designed to meet retention requirements only, then outlet control structure shall be designed to dewater the **required retention volume** (RRV) within the specified drawdown time as follows:
  - Determine the design head on the orifice at or near the outfall (h_o), equal to one half of the sum of the media depth above the orifice (dm) and the maximum ponding depth in the facility (h_{max}).

Equation 5606-4:

$$h_0 = \frac{1}{2} \sum d_m + h_{max}$$

h_o = Design head above underdrain (ft)

d_m = Depth of media layer(s) above orifice (ft

h_{max} = Maximum ponding depth (ft)

  - Determine the average rate of flow to orifice to drain the RRV within the specified drawdown time:

Equation 5606-5:

$$Q_{avg} = \frac{RRV}{t_{max}}$$

Q_{avg} = Average rate of flow to the underdrain (cfs)

RRV = Required retention volume tributary to the GSI (ft^3)

t_{max} = Maximum drawdown time (seconds)

  - Determine the underdrain area required to drain the average flow rate using the orifice equation:

Equation 5606-6:

$$Q_{avg} = 0.6 * A \sqrt{2 * g * h_o}$$

Q_{avg} = Average rate of flow to the underdrain (cfs)

0.6 = Discharge coefficient

A = Cross-sectional area of underdrain (ft^2)

g = Acceleration of gravity, 32.2 ft/s^2

h_o = Design head above underdrain (ft)

9.2 OUTLET CONTROL STRUCTURE (cont.)

- At least 1" of freeboard shall be provided above the outlet elevation. If storms larger than the RRV are routed through the GSI, the water surface elevation above the outlet shall be determined, and at least 1" of freeboard above that elevation must be provided. The 10-year design storm shall either bypass the GSI, or pass through the designated outlet(s), including an overflow weir or spillway, without overtopping the basin.
- Control mechanism (weir, orifice, or valve) elevations internal to the outlet control structure shall consider the designed elevations within the GSI storage media. It is recommended that these elevations are set no higher than the finished grade of the surface media.
- Designer shall specify control mechanism type size, and configuration, as applicable. Designer shall consider blinding potential of valves and orifices that impact rate of stormwater release from the GSI facility. Specify valve open/close parameters for during and after construction, as applicable.
- Manufactured outlet control structure standard detail is often provided by the manufacturer. Designer shall review detail and provide additional information as needed to define water level control function of the GSI facility.
- Overflow elevations shall be set at the design ponding height. Ponding volume above the overflow elevation is not recognized as storage volume in the GSI as it is assumed to discharge through the outlet and bypass the facility.
- Designer is required to evaluate the impact of the outflow from the GSI to the downstream drainage system by providing existing and proposed hydraulic grade line elevations.
- Designer shall provide an anchoring design for the outlet control structure to mitigate flotation of the structure, as applicable.
- Designer shall consider specifying a catch basket or strainer product within in the outlet structure to minimize debris exiting the facility.
- For CMAC technology, the following requirements apply:
  - The automated valve shall be connected to the primary control structure.
  - A "fail-safe mode" setting must be incorporated to ensure that if the CMAC system loses power or experiences any other faults, the automated valve will be set to open and provide the same level of detention as a passive primary control structure.
  - The CMAC system must be programmed to provide pre-event drawdown to account for forecast precipitation.
  - The CMAC system must be programmed to retain precipitation events up to or above the 2-year storm for at least 72 hours prior to beginning draw down.
  - Drawdown rates through the primary outlet cannot exceed the allowable peak flow for the 2-year storm.

Outlet control structure designs outside of the parameters of this guideline shall be submitted for review and approval.

5606.10 GSI-10 STORAGE CHAMBERS

Storage chambers are the primary storage component for subsurface storage and additional storage for other **GSI Practices**. Storage chambers provide structural support for open subsurface storage allowing for larger void volume than storage aggregate media. Stormwater stored within the chambers is either temporarily detained and released through an outlet structure, allowed to infiltrate through the bottom of the storage chamber, or a combination of both.

DESIGN DELIVERABLE CHECKLIST

- Specify in-situ infiltration testing locations and frequency for all GSI Practices. Reference Specification Section 02956 Green Stormwater Infrastructure In-situ Infiltration Testing for recommended test methodology.
- Storage capacity calculations including tributary drainage area, impervious tributary area, **required retention volume** (RRV), soil and aggregate component **retention storage volume**, and storage volume provided by retention practices (V_R), including any ponding depth, if applicable.
- Calculations or manufacturer's certification stating that the system meets the required design loading requirements.
- Plan view of GSI Practice specifying extents of subsurface storage with northing/easting points and elevations.
- Grading plan shall identify Survey Verification Points along the top and bottom of the side slope, finished surface, and spot elevations of the GSI for contractor verification during construction.
- Detail/Section view of GSI Practice specifying type, spacing, and/or layout of subsurface storage, with depth of aggregate media layers (as applicable), referencing material specifications.
- If propriety system is used, design shall reference to manufacturer's standards and specifications
- Specify depth or elevation within storage chambers for which 10% of the total storage volume is met, and specify contractor demarcation of depth on installed chamber to clearly indicate the depth of sediment accumulation at which clean-out is required.
- Detail of anchoring design to prevent flotation (as applicable)

Rendering of Pretreatment & Underground Storage Chambers

10.1 STORAGE VAULTS

Description:

Storage vaults are below grade structures that retain or detain stormwater runoff directed to the underground structure. Storage vaults with open bottoms encourage infiltration into underlying soils when the outlet discharge elevation is above the bottom elevation of the storage vault. For open-bottomed storage vaults, the volume of stormwater storage below the outlet elevation is said to be "retained", while the volume of stormwater storage above the outlet elevation is only temporarily stored or "detained". Storage vaults with a solid bottom are designed to temporarily store stormwater runoff, attenuating and reducing peak flows by controlling the release rate of stored stormwater through an outlet. Solid-bottomed storage vaults provide stormwater detention only, as no stormwater is able to infiltrate into the underlying soils.

Where to Use:

Storage vaults are most commonly used in subsurface storage and cistern GSI Practices. Storage vaults in subsurface storage applications are typically of concrete material and used to temporarily detain stormwater. However, when the storage vault has an open bottom, it allows stormwater to infiltrate into the underlying soils. Concrete storage vaults are often used on sites that require large volumes of stormwater to be stored in a smaller footprint. Storage vaults in cistern applications for rainwater harvesting are typically of plastic material.

Design Considerations:

The following are recommendations and considerations for designing GSI with a storage vault component. As many storage vaults are proprietary products, design professional shall specify a manufactured product (or approved equal) or develop a specification for the construction and material requirements based on the project design.

- ➔ If proprietary system is used, design shall conform to manufacturer's standards and specifications
- ➔ Designer shall specify compaction of the underlying soils based on the intended function of the storage vault (to temporarily detain or to infiltrate stormwater).
- ➔ Designer shall specify soil and/or aggregate cover material type and depth needed to meet the loading requirements or intended use of the finished grade above it.
- ➔ Designer shall specify a storage vault product/ material capable of withstanding live loads due to traffic (if applicable).
- ➔ Designer shall specify a storage vault product/ material capable of withstanding dead loads incurred by overlying soil, pavement, structures, etc. (if applicable).
- ➔ Designer shall account for effects of buoyancy; specify a storage chamber product/material with anchoring and/or appropriate cover to prevent flotation as applicable.
- ➔ Designer shall include access points for convenient inspection and cleaning of the storage vault(s). For applications where confined space entry will be necessary, round access openings scaled to similar size as typical sewer manholes are preferred to allow convenient tripod placement.

10.2 STORAGE PIPES

Description:

Storage pipes are below grade piped systems that retain or detain stormwater runoff conveyed to the pipes. Perforated storage pipes encourage infiltration into underlying soils depending on the configuration of the outlet control. For perforated storage pipes, the volume of stormwater stored and infiltrated is said to be "retained". Solid- walled storage pipes that temporarily store stormwater runoff attenuate and reduce peak flows by controlling the release rate of stored stormwater through an outlet. Solid-walled storage pipes provide stormwater detention only, as no stormwater is able to infiltrate into the underlying soils.

Where to Use:

Storage pipes are typically used in subsurface storage GSI Practices or to provide additional subsurface storage for other GSI Practices. Storage pipes may be found in-line or off-line from the storm or combined sewer system when detention is needed to attenuate peak flows for the downstream system.

Design Considerations:

The following are recommendations and considerations for designing GSI with a storage pipe component. Refer to Specification Section 02954 Green Stormwater Infrastructure Piping for specific construction and material requirements.

- ➔ If proprietary system is used, design shall conform to manufacturer's standards and specifications.
- ➔ Designer shall specify compaction of the underlying soils based on the intended function of the storage pipe (to temporarily detain or to infiltrate stormwater).
- ➔ Designer shall specify the height, width, and length of storage pipe that provides the desired storage volume based on site space constraints to meet retention and/or detention requirements.
- ➔ Designer shall specify soil and/or aggregate cover material type and depth needed to meet the loading requirements or intended use of the finished grade above it.
- ➔ Designer shall specify a storage pipe material capable of withstanding live loads due to traffic (if applicable).
- ➔ Designer shall specify a storage pipe material capable of withstanding dead loads incurred by overlying soil, pavement, structures, etc. (if applicable).
- ➔ Designer shall account for effects of buoyancy; specify anchoring and/or appropriate cover to prevent flotation as applicable.
- ➔ Designer shall include access points for convenient inspection and cleaning of the storage pipe(s). For applications where confined space entry will be necessary, round access openings scaled to similar size as typical sewer manholes are preferred to allow convenient tripod placement.

10.3 ARCH CHAMBERS

Description:

Arch chambers are below grade structures, typically of plastic material, with open bottoms, that retain or detain stormwater runoff directed to the underground structure. Arch chambers encourage infiltration into underlying soils when the outlet discharge elevation is above the bottom elevation of the storage vault. The volume of stormwater storage below the outlet elevation is said to be "retained", while the volume of stormwater storage above the outlet elevation is only temporarily stored or "detained".

Where to Use:

Arch chambers are most commonly used in subsurface storage GSI Practices. They may also be used to provide additional subsurface storage for other GSI Practices.

Design Considerations:

The following are recommendations and considerations for designing GSI with an arch chamber component. As many arch chambers are proprietary products, design professional shall specify a manufactured product (or approved equal) or develop a specification for the construction and material requirements based on the project design.

- ➔ If proprietary system is used, design shall conform to manufacturer's standards and specifications.
- ➔ Designer shall specify compaction of the underlying soils based on the intended function of the arch chambers (to temporarily detain or to infiltrate stormwater).
- ➔ Designer shall specify soil and/or aggregate cover material type and depth needed to meet the loading requirements or intended use of the finished grade above it.
- ➔ Designer shall specify an arch chamber product/ material capable of withstanding live loads due to traffic (if applicable).
- ➔ Designer shall specify an arch chamber product/ material capable of withstanding dead loads incurred by overlying, soil, pavement, structures, etc. (if applicable).
- ➔ Designer shall include access points for convenient inspection and cleaning of the arch chamber(s). For applications where confined space entry will be necessary, round access openings scaled to similar size as typical sewer manholes are preferred to allow convenient tripod placement.

10.4 STORAGE CRATES

Description:

Storage crates are below grade structures, typically of plastic material, with perforated sides, that retain or detain stormwater runoff directed to the underground structure. Storage crates encourage infiltration into underlying soils when the outlet discharge elevation is above the bottom elevation of the storage crates. The volume of stormwater storage below the outlet elevation is said to be "retained", while the volume of stormwater storage above the outlet elevation is only temporarily stored or "detained".

Where to Use:

Storage crates may be used in areas with site constraints warranting unique configurations for stormwater storage. These crates come in a variety of sizes and can be stacked to form unique storage shapes to meet storage requirements within the available space. Storage crates shall not be used within the public right-of-way when it is a utility dense corridor subject to frequent excavation and utility relocation due to the challenges of ensuring the integrity of the GSI Practice and its subsurface design components during disturbance.

Design Considerations:

The following are recommendations and considerations for designing GSI with a storage crate component. As many storage crates are proprietary products, design professional shall specify a manufactured product (or approved equal) or develop a specification for the construction and material requirements based on the project design.

- ➔ If proprietary system is used, design shall conform to manufacturer's standards and specifications.
- ➔ Designer shall specify compaction of the underlying soils based on the intended function of the storage crates (to temporarily detain or to infiltrate stormwater).
- ➔ Designer shall specify soil and/or aggregate cover material type and depth needed to meet the loading requirements or intended use of the finished grade above it.
- ➔ Designer shall specify a storage crate product capable of withstanding live loads due to traffic (if applicable).
- ➔ Designer shall specify a storage crate product capable of withstanding dead loads incurred by overlying, soil, pavement, structures, etc. (if applicable).
- ➔ Designer shall include access points for convenient inspection and cleaning of the storage crates.

10.5 GREEN ROOF DRAINAGE LAYER

Description:

A drainage layer is typically incorprated into green roofs to quickly remove excess water from the vegetation root zone. The selection and thickness of the drainage layer type is an important design decision that is governed by the desired stormwater storage capacity, the required conveyance capacity, and the structural capacity of the rooftop. A wide range of prefabricated water cups, plastic modules or foam-type materials can be used, as well as a traditional system of protected roof drains, conductors, and roof leaders.

Where to Use:

Green roof drainage layers are placed between the rooftop and the green roof growing media, often with a root-permeable liner above and a root barrier between the drain layer and the roof's waterproofing layer.

Design Considerations:

The following are recommendations and considerations for designing a green roof drainage layer.

- Many green roof drainage layers are proprietary products associated with a specific green roof manufacturer. All manufacturer specifications should be followed.
- Green roof drainage layers typically provide both permanent storage and drainage functions.
- Green roof drainage layer storage is not calculated based on porosity, but on the maximum water retention of the media, which is determined using the methods described by ASTM tests E2398, and E2399, as appropriate.
- Particular care must be taken around roof inlets to ensure that roofs with green roof GSI do not hold excess water.

5606.11 GSI-11 INTERNAL CONTROL, PROTECTION, & STABILIZATION

The purpose of internal control, protection, and stabilization components are to:

- **Controlling** the collection, conveyance, and runoff of stormwater within and entering the site
- **Protecting** the GSI from clogging with sediment during construction
- **Stabilizing** the on-site soils throughout the establishment period

Projects with **GSI Practices** must include internal control and protection measures to safeguard the GSI Practices and components against erosion and sedimentation from the contributing site during construction and into the establishment phase. Erosion and sedimentation from the contributing site or within the GSI Practice can degrade its function by clogging soil and aggregate media, media liners, and piping. This can reduce or prohibit infiltration and increase ponding durations and volumes, harming or killing vegetation and reducing treatment and storage capacities.

These internal control, protection, and stabilization measures are in addition to traditional erosion and sediment control requirements to prevent or minimize pollution caused by runoff from the construction site. Many of the internal control, protection, and stabilization components are similar to traditional erosion and sediment control measures; however, they are applied differently and require thoughtful placement, construction, and phasing. While traditional erosion and sediment control focuses on stormwater, sediment and pollutants leaving the site, internal control and protection address these issues within the site to protect the GSI.

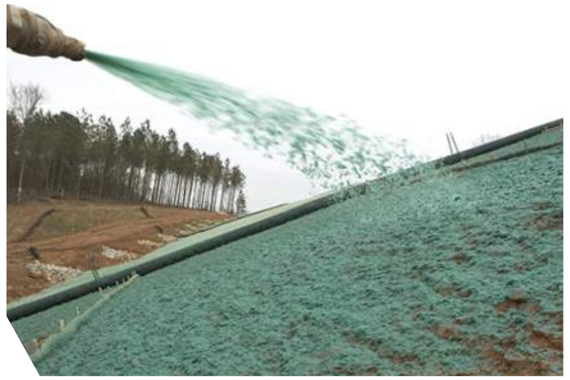
DESIGN DELIVERABLE CHECKLIST

Site Activity Plan and Detail Drawing(s), including:

- Plan view(s) showing extents of each GSI Practice and surrounding site
- Existing contours and existing drainage paths or flow arrows
- Proposed contours and proposed drainage paths or flow arrows
- Delineation of GSI boundaries with callouts for type of GSI Practice, name of GSI Practice, and reference to relevant site plan drawing(s)
- Callouts for **GSI Components** within each GSI Practice requiring control and protection
- GSI areas requiring control and protection measures and limitations on use of those areas throughout construction
- Types and locations of control and protection measures
- Details of control and protection measures, including acceptable material and installation
- Delineation of Tree Protection Zones outside of the GSI
- Notes describing maintenance requirements for control and protection measures, including timing for installation, replacement, and permanent removal
- Construction phasing and sequencing relative to the GSI facility(ies) including temporary irrigation requirements for vegetation establishment considering watering source, connection, distribution, and removal.

Cover Material

Hydraulic Application



Erosion Control Blanket

Turf Reinforcement Mat

Tied Concrete Block Mat

11.1 STABILIZATION

Description:

Until vegetation is established, stormwater flowing across or down slopes, through channels, and into planting beds can cause significant erosion and sedimentation within or surrounding GSI Practices. Designers specify stabilization measures to supplement the vegetation to resist erosive velocities.

GSI 11.1.1 Cover Material:

A protective layer applied to the soil surface for the establishment of temporary or permanent vegetation. Typical cover materials include straw, compost, various mulches , and landscaping rock/aggregate.

GSI 11.1.2 Hydraulic Application:

A homogeneous application of soil amendments, mulch, tackifying agents, bonded fiber matrix, and liquid co- polymers onto soil. Hydraulic applications may also include temporary (GSI-11.2) or permanent (GSI-7.5) seed mixes.

GSI 11.1.3 Erosion Control Blanket (ECB):

An open-weave web of interlocking fibers with net backing. Fiber material is typically biodegradable straw, wood, or coconut fiber material that degrades or dissipates on its own without removal.

GSI 11.1.4 Turf Reinforcement Mat (TRM):

A three- dimensional synthetic fiber mat that is typically nondegradable due to the fibers, filaments, nettings, and/or wire mesh that are processed into the matrix, providing permanent stabilization.

GSI 11.1.5 Tied Concrete Block Mat:

A mat made of concrete blocks tied together with geogrid or cables to provide permanent stabilization. Vegetation growth through the geogrid is dependent on manufacturer recommendations. These may also be referred to as articulated concrete block mats.

Where to Use:

Stabilization measures shall be employed when bare soil, steep slopes, stormwater inflow, and water flow into, within or through a GSI Practice could potentially mobilize along slopes or deposit soil onto level surfaces. The practices shall be installed as soon as discrete areas or phases of mass grading or fine grading are completed or prior to significant periods of inactivity. Permanent stabilization measures such as turf reinforcement mats or tied concrete block mats shall be used where stormwater flows are concentrated and/ or where shear stresses of stormwater flow exceed the allowable shear stress of the established vegetation and soils.

Design Considerations:

The following are recommendations and considerations for designing GSI with stabilization measures. Designer shall reference product or manufacturer specifications and/or American Public Works Association (APWA) Specification Section 2150 for construction and materials specific requirements.

- Stabilization measures shall be provided wherever stormwater is conveyed into, through, and out of a GSI Practice. This includes the perimeter of the GSI for facilities receiving sheet flow.
- Selection of stabilization measures and their placement should be based on factors such as length of flow, velocity, shear stress, and soil type.
- Cover Material, Hydraulic Application and/or Erosion Control Blanket stabilization measures shall be considered for slopes 6:1 (H:V) or steeper.
- Permanent stabilization measures such as Turf Reinforcement Mats and Tied Concrete Block Mats shall be considered at pipe end sections into GSI Practices, **engineered channels** at **overflow spillways**, on the downstream side of surface weirs, or when other stabilization measures are insufficient to resist erosive flows.
- Designers shall also consider where scour or sediment deposition could occur on more gentle slopes or level areas and apply stabilization measures to prevent soil mobilization and negative impacts from deposition.

Temporary Seed

Cover Crop Seed

11.2 SUPPLEMENTAL SEEDING

Description:

Supplemental seeding is the application of seed to bare soil to prevent erosion and/or encourage growth of native grass or wildflowers. The vegetations' root systems grasp the soil and create protection from wind and stormwater to reduce erosion.

GSI 11.2.1 Temporary Seed:

Fast-growing annual grass or small grain seed applied to exposed or disturbed soil to temporarily stabilize the area. The vegetative cover reduces erosion from stormwater runoff until permanent vegetation is planted. Temporary Seed shall be installed when site or seasonal conditions do not allow for seeding or sodding of the permanent type specified.

GSI 11.2.2 Cover Crop Seed:

Annual grain seed applied to an area to assist in the establishment of native grasses, wildflowers, or perennials by reducing weeds. Like temporary seed, the vegetative cover reduces erosion until the permanent vegetation is established.

Where to Use:

Supplemental seeding shall be used where any cleared, unvegetated, or sparsely vegetated soil lays idle and is not subjected to construction traffic. Supplemental seeding is commonly applied to topsoil stockpiles, embankments, temporary sediment basins, and other areas of steep slope.

Design Considerations:

The following are recommendations and considerations for designing GSI with vegetative stabilization. Refer to Section 02953 Green Stormwater Infrastructure Non-Native Seeding and Sodding for construction and materials specific requirements.

- ➔ Supplemental seeding may be considered for application with other stabilization methods (GSI-11.1) to protect from erosion while the seed germinates.
- ➔ Consider planting windows for permanent vegetation before specifying supplemental seeding.
- ➔ Select species that are compatible with permanent vegetation and that will help prepare planting areas.

11.3 PERIMETER AND SURFACE PROTECTION

Description:

Perimeter and surface protection provides a physical barrier around the footprint or over the surface material of the GSI Practice or GSI Component (such as inlets) to impede or divert stormwater and/or capture sediment. While stabilization measures (GSI-11.1) shall be considered first to prevent erosion before it occurs, perimeter and surface protection can be used in conjunction with these measures to provide additional protection during active soil-disturbing construction activities. Providing control and protection limits the potential for clogging and damage to the GSI Components and media layers. Multiple perimeter and surface protection measures can be applied together to provide more resilient defense against erosion and sedimentation.

GSI 11.3.1 Silt Fence:

A vertical barrier of geotextile fabric to impede the migration of silt and sediment.

GSI 11.3.2 Erosion Control Logs:

Also commonly referred to as biologs or wattles, are typically used as inlet protection for traditional erosion control measures. However, Erosion Control Logs can also be applied linearly around a GSI facility or component to block loose soil, sediment, and debris from entering the GSI Practice or component. Common types of erosion control logs include coconut coir, straw, wood, and compost-filled filter socks. Sandbags are not appropriate for use as they have a high risk of breaking and contaminating the adjacent GSI media.

GSI 11.3.3 Geotextile Liner Surface Protection:

The use of permeable geotextile liners to cover the surface of GSI Practices to prevent clogging due to migration of soil from adjacent areas.

Where to Use:

Perimeter and surface protection measures shall be installed around GSI facilities or components after they are installed and/or at stormwater inflow locations, grade transitions (top or toe of slope), at intervals within long or steep slopes, and anywhere where sheet flow, shallow concentrated flow or channel flow may mobilize or deposit soil into a GSI facility or component. Multiple measures may be installed in combination or in series to provide effective management. Geotextile Liner may be used in conjunction with other perimeter protection measures as secondary protection of the GSI facility soil and/or aggregate media.

Silt Fence

Erosion Control Log

Surface Protection Before Rain

Surface Protection After Rain

11.3 PERIMETER AND SURFACE PROTECTION (cont.)

Design Considerations:

The following are recommendations and considerations for designing GSI control and protection measures. Designer shall reference product or manufacturer specifications and/or AWPA Section 2150 and Section 02939 Green Stormwater Infrastructure Media Liners for construction and materials specific requirements.

- ➔ Use perimeter protection, such as erosion control logs, to barricade inlets (GSI-1) that discharge to GSI Practices after they are constructed.
- ➔ Provide perimeter protection, such as silt fence or erosion control logs, surrounding GSI Practices that rely on infiltration (e.g. rain gardens, bioretention, infiltration trenches) to prevent migration of adjacent soils onto the GSI Practice. Designer should consider specifying both silt fence and erosion control logs to protect against failure of a single control and protection measure. Designer shall specify type of erosion control logs that are acceptable for the GSI application. Straw wattles can be less effective if not properly installed.
- ➔ Consider the use of Geotextile Liner Surface Protection to protect GSI Practices that rely on infiltration through permeable media in the event that perimeter protection measures, such as silt fence, fail.

11.4 TEMPORARY FLOW CONTROL

Description:

Temporary flow control measures help reduce the introduction of sediment from piped stormwater collection systems into GSI facilities and prevent discharges from outlet pipes within the GSI prior to the facility being ready to accept the stormwater flows once plant establishment has achieved stabilization of the ground surface. These measures reduce the velocity of flows entering GSI facilities or temporarily bypass those flows around the GSI facility completely.

GSI 11.4.1 Check Dams:

Small obstructions constructed in the path of stormwater flow, perpendicular to the direction of flow, to reduce velocity and prevent erosion. Check dams are typically installed in drainage ditches, swales, or channels and can be built out of various materials including stone, logs, or sandbags filled with gravel.

GSI 11.4.2 Bypass Piping:

A temporary pipe system that collects and conveys flow that would be discharged to a GSI facility to an appropriate location downstream. Bypass piping for a subsurface enclosed system typically includes temporary connections to existing drainage systems not connected to the GSI facility. Surface systems, such as roof drains and discharging storm sewers at the surface, can connect flexible piping to the discharge point that extends around and downstream of the GSI facility.

GSI 11.4.3 Weir Plate:

A temporary plate installed at the end of the enclosed pipe system to limit the velocity and quantity of stormwater discharging to a GSI facility.

GSI 11.4.4 Pipe Plug:

A temporary device installed within an enclosed pipe to prevent flow from being conveyed into or through the piped system.

GSI 11.4.5 Soil Berm:

A temporary compacted berm of native or imported soil or mulch that diverts stormwater around the GSI facility or component.

Check Dams

Bypass Piping

Weir Plate

Soil Berm

Where to Use:

Ideally, stormwater should not be introduced into a GSI facility until the contributing drainage area and GSI Practice are fully stabilized with vegetation. Where practical, inflow points shall be closed off or stormwater directed to bypass around the GSI facility to the downstream system. Outlet structures that discharge into surface channels or water bodies shall also be protected to prevent GSI facilities from mobilizing sediment and creating new erosion and sediment deposition problems that are transferred downstream.

Design Considerations:

The following are recommendations and considerations for designing GSI enclosed system control.

- ➔ Specify the size, material, and spacing of Check Dams to obstruct flow, reduce velocity and prevent erosion in drainage ditches, swales, or channels. Check dams are typically installed in and can be built out of various materials including stone, logs, or sandbags filled with gravel.
- ➔ Feasibility of bypass piping around the GSI facility shall be evaluated. Consider for which rainfall events the bypass piping has capacity and what additional protection measures may be necessary for events larger than the piping capacity.
- ➔ Evaluate the use of a temporary weir plate on piped system that discharges to a GSI facility, to reduce inflow to the facility. Consider drainage paths that will be utilized if flow is prevented to enter or leave the GSI facility via the piped system.
- ➔ Specify the size, shape, and location of pipe plugs to be installed to pipe systems to prevent piped flow into or from GSI facilities. Consider drainage paths that will be utilized if flow is prevented to enter or leave the GSI facility via the piped system.
- ➔ Consider ease of removal for temporary pipe plugs or weirs when specifying a manufactured product.

5607

DESIGN CRITERIA FOR COLLECTION PRACTICES

5607 DESIGN CRITERIA FOR COLLECTION PRACTICES

5607.1 COLLECTION PERFORMANCE REQUIREMENTS

Stormwater collection practices capture stormwater runoff from the ground surface and route it to another component of the storm drainage system. Collection requirements in the following categories are defined for vehicular areas to maintain safe travel ways:

1. Traditional Inlets - Roads < 45 miles per hour (MPH)
2. Traditional Inlets - Roads ≥ 45 miles per hour (MPH)
3. Parking Lots
4. Roadway Retention

Collection of runoff can be achieved using traditional inlet structures, roadway retention GSI practices (**Section 5605**), or a combination of both.

- Traditional Inlets: Traditional inlet placement for roadways references and utilizes the criteria defined by Hydraulic Engineer Circular No. 22 (HEC-22) Urban Drainage Design Manual. Inlet calculations are based on design speeds, roadway cross slopes and stormwater design level of service. Cross slopes will change based on how the roadway is constructed and maintained.
- Roadway Retention: the integration of green stormwater infrastructure (GSI) practice into the roadway to meet the required retention volumes (RRV). This can be achieved using standard roadway retention GSI Practices (**5605.3**) or designed specific to the project per **Section 5605**.

Table 5602-8 (**Section 5602.4, A.**) summarizes the stormwater collection performance requirements.

A. Background: Roadway Design Criteria & Stormwater

The approach to designing collection practices for roads follows the principles of the Safe System Approach (**https://www.transportation.gov/NRSS/SafeSystem**), which has been adopted by the U.S. Department of Transportation (USDOT) Federal Highway Administration (FHWA). These principles include:

- Deaths and serious injuries are unacceptable
- Humans make mistakes
- Humans are vulnerable
- Responsibility is shared
- Safety is proactive
- Redundancy is crucial

The Safe System approach is committed to zero traffic deaths, which means addressing all aspects of safety through the following five Safe System elements that, together, create a holistic approach with layers of protection for road users:

1. Safe Road Users
2. Safe Vehicles
3. Safe Speeds
4. Safe Roads
5. Post-Crash Care

The Role of Stormwater and Retention in the Roadway

Even a thin layer of water on the travel way surface can initiate motor vehicle hydroplaning at speeds as low as 35 MPH (**www.dmv.pa.gov**, 9/4/2024). Travel ways are generally designed to move runoff from a highpoint near the road center towards the edge of the pavement (cross slope). Roadside retention utilizing GSI practices supports the Safe System approach by incorporating the following:

- Redundancy for traditional inlets
- Reducing peak flow
- Promoting safety by defining an intentional area for runoff infiltration

Speed & Stormwater

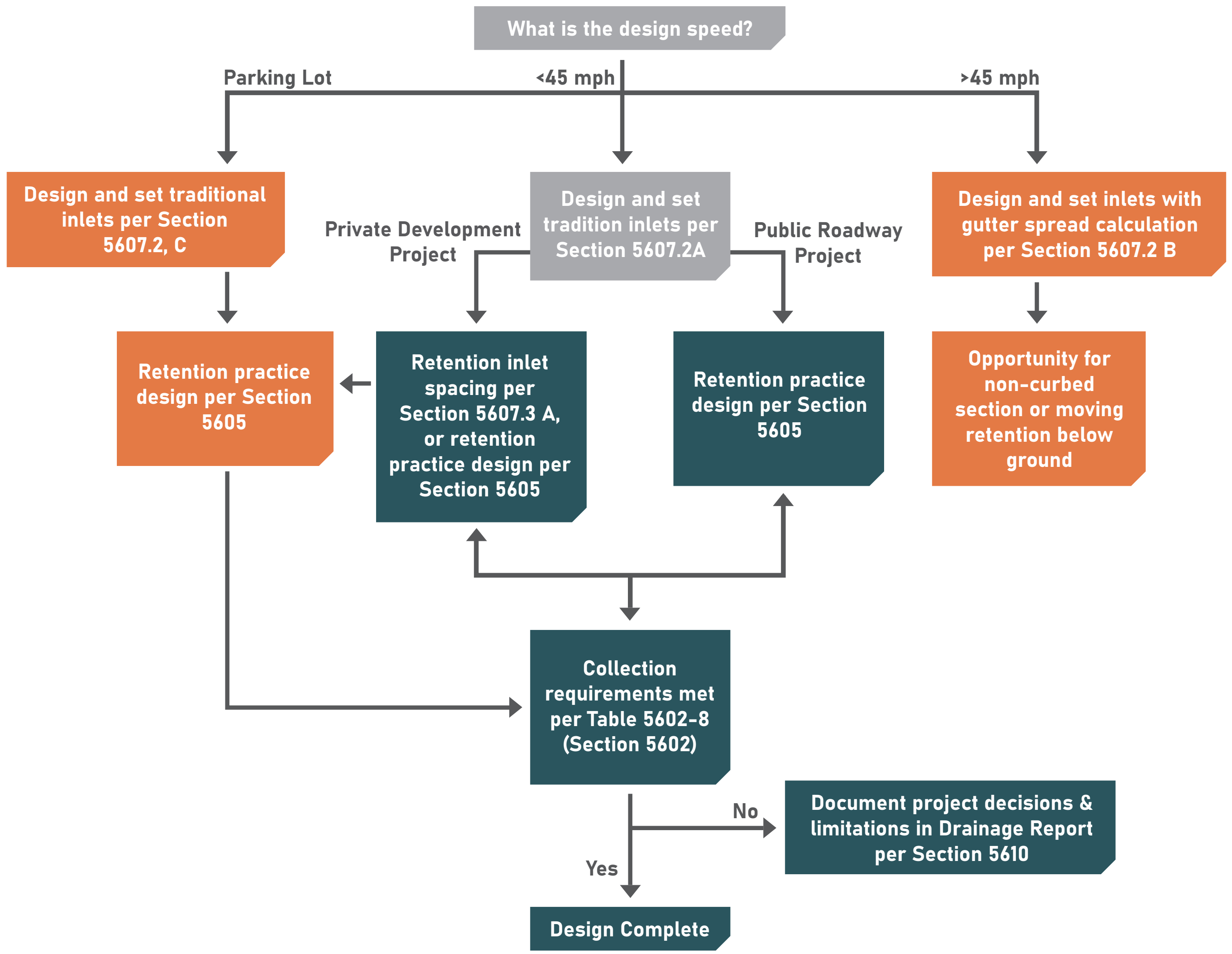
Incorporation of GSI practices into the roadway based on the design speed supports the focus of the Safe Systems approach where, "Speed is at the heart of a forgiving road transport system..." (**https://highways.dot.gov/safety/zero-deaths**). The traditional inlet and GSI practice integration criteria for roadways are based on speed, and then modified as necessary to address road uses as a whole system. This approach reduces both the likelihood and consequences of human error.

Vehicular speed defines a starting point for stormwater collection design. This can be modified based on how the road will function within the community.

Roadway Retention & Collection Approach

The purpose of the Figure 5607-1 is to guide designers through the process of incorporating both traditional inlets and GSI practices into a roadway design.

Figure 5607-1: Integration of Stormwater Collection to the Roadway System



5607.2 TRADITIONAL INLET REQUIREMENTS

A. Traditional Inlet Requirements – Roads Speeds < 45 MPH

Traditional inlet spacing along roads with speeds of less than 45 MPH are specified by typical road slope, cross section, and lane width. At a minimum, traditional inlets shall be evaluated and placed as follows:

- **Assess Existing Inlets**. All existing inlet locations impacted by the project shall be reassessed to evaluate effectiveness of stormwater collection for post-project conditions. When necessary, existing inlets shall be relocated to improve stormwater collection and align with the post-project uses for the roadway cross-section. This includes the effective capture of stormwater from post-project sump locations, as these may differ from pre-project conditions.
- **Sump Locations**. Inlets shall be installed in all sump locations within the roadway longitudinal profile;
- **Intersection Low Points**. Inlets should be installed at localized low points in an intersection, with care taken to avoid having the ADA ramp be within the low point.
- **Decision Points**. Inlets should be considered at locations along the roadway alignment where the driver must react, such as pedestrian crossings and intersection locations, upgradient of the localized low points.

Minimum Frequency of Inlet Placement. Inlets shall be placed at regular intervals as related to longitudinal slope and roadway cross slope shown in Table 5607-1, Table 5607-2, Table 5607-3, and Table 5607-4. The frequency of inlet placement was calculated in accordance with the most current version of Chapter 7 of the Urban Drainage Design Manual, Hydraulic Engineering Circular No.22 (HEC-22) by the U.S. Department of Transportation Federal Highway Administration.

Inlet spacing tables assume runoff from a typical cross-section that receives runoff from the roadway (12-foot lanes with 1.5' curb and gutter) and surrounding right-of-way including sidewalks (5-foot wide). Spacing values were rounded up to the nearest 50-feet to adequately meet gutter spread requirements for variable cross-sections. Standard inlet spacing tables shall not be used for roadway designs with run-on from outside of right-of-way or with road cross-sections that vary substantially from these assumptions. In these instances, HEC-22 shall be used to determine inlet placement to meet gutter spread requirements.

Table 5607-1: Standard Traditional Inlet Spacing for 1-Lane Road, Maximums (10-Year Design Storm)

Longitudinal Slope, S_l (%)	Linear Frequency of Inlet Placement
1.0%	**1 inlet every 200 feet** (about a half block of drainage area per inlet)
1.5%	**1 inlet every 300 feet** (about a block of drainage area per inlet)
2.0%	
2.5%	
3.0%	**1 inlet every 400 ft** (about a block and a half of drainage area per inlet)
3.5%	
4.0%	**1 inlet every 500 feet** (about two blocks of drainage area per inlet)
4.5%	
5.0%	
5.5%	
6.0%	
6.5%	
7.0%	

Note: The calculations are based on an assumed 2% roadway cross slope and a 1.5 foot gutter width.

Table 5607-2: Standard Traditional Inlet Spacing for 2-Lane Road, Maximums (10-Year Design Storm)

Longitudinal Slope, S_l (%)	Linear Frequency of Inlet Placement
1.0%	**1 inlet every 150 feet** (about three quarters of a block of drainage area per inlet)
1.5%	**1 inlet every 200 feet** (about a half block of drainage area per inlet)
2.0%	
2.5%	
3.0%	**1 inlet every 300 feet** (about a block of drainage area per inlet)
3.5%	
4.0%	
4.5%	
5.0%	
5.5%	**1 inlet every 400 ft** (about a block and a half of drainage area per inlet)
6.0%	
6.5%	
7.0%	

Note: The calculations are based on an assumed 2% roadway cross slope and a 1.5 foot gutter width.

Table 5607-3: Standard Traditional Inlet Spacing for 3-Lane Road, Maximums (10-Year Design Storm)

Longitudinal Slope, S_l (%)	Linear Frequency of Inlet Placement
1.0%	**1 inlet every 100 feet** (about a quarter block of drainage area per inlet)
1.5%	**1 inlet every 150 feet** (less than a half block of drainage area per inlet)
2.0%	
2.5%	**1 inlet every 200 feet** (about a half block of drainage area per inlet)
3.0%	
3.5%	
4.0%	
4.5%	
5.0%	**1 inlet every 300 feet** (about a block of drainage area per inlet)
5.5%	
6.0%	
6.5%	
7.0%	

Note: The calculations are based on an assumed 2% roadway cross slope and a 1.5 foot gutter width.

Figure 5607-2: Traditional Inlet Spacing & Gutter Spread

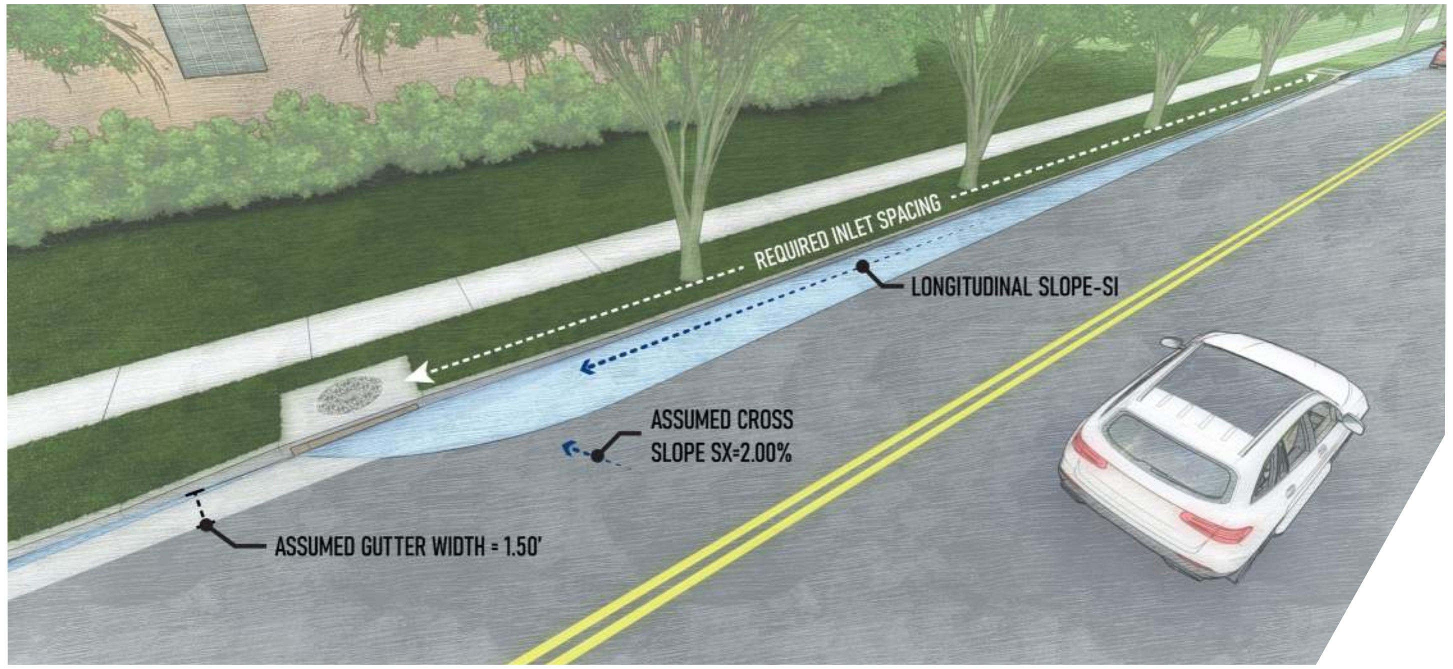


Table 5607-4: Standard Traditional Inlet Spacing for Two-Way Left Turn Lane (10-Year Design Storm)

Longitudinal Slope, S_l (%)	Linear Frequency of Inlet Placement
1.0%	**1 inlet every 200 feet** (about a half block of drainage area per inlet)
1.5%	
2.0%	
2.5%	**1 inlet every 300 feet** (about a block of drainage area per inlet)
3.0%	
3.5%	
4.0%	**1 inlet every 400 ft** (about a block and a half of drainage area per inlet)
4.5%	
5.0%	
5.5%	
6.0%	**1 inlet every 500 ft** (about two blocks of drainage area per inlet)
6.5%	
7.0%	
Note: The calculations are based on an assumed 2% roadway cross slope and a 1.5 foot gutter width.	

B. Roadway Speeds ≥ 45 MPH

Traditional Inlet Requirements – Roads Speeds ≥ 45 MPH

Traditional inlets shall be designed using NOAA Nested Rainfall Distributions defined in Section 5603. Design shall be in accordance with the most current version of Chapter 7 of the Urban Drainage Design (HEC-22) Manual, Hydraulic Engineering Circular No.22 (HEC-22) by the U.S. Department of Transportation Federal Highway Administration. Chapter 7 discusses inlet types and uses, hydraulic efficiency, clogging potential, and bicycle and pedestrian safety applicable to the design of inlets. Inlets shall be placed to limit the width of flow in street gutters (gutter spread) at the time of peak discharge for the design storm.

C. Parking Lots

Traditional Inlet Requirements – Parking Lots

Inlets should be placed in sump locations as necessary. Parking lot grading shall facilitate positive drainage to inlets and/or retention practices. Inlets should also be located to intercept runoff prior to leaving the site as necessary to meet stormwater management requirements defined in **Section 5602**. Gutter spread calculations are not required for inlet placement in parking lots.

Roadway Retention – Parking Lots

Roadway retention requirements for parking lots should follow the performance requirements defined in Section 5602 with design of GSI practices per Section 5605. Collection and retention requirements can be met concurrently by utilizing GSI practices for collection within parking lot islands, medians, and around the perimeter of the parking lot. Integration of GSI practices in these areas also creates the opportunity to meet other project landscaping and screening requirements associated with the site design.

5607.3 ROADWAY RETENTION

A. Roadway Retention – Roadway Speeds < 45 MPH

Roadway retention performance requirements are defined in Table 5602-8 (**Section 5602**). Retention practices shall be designed per **Section 5605**. **Section 5605.3** defines standardized roadway GSI practices that may be applied at a defined spacing interval to meet requirements for public roadway redevelopment projects

B. Roadway Retention–Roads Speeds ≥ 45 MPH

Roadway retention performance requirements are defined in Table 5602-8 (**Section 5602**). Retention practices shall be designed per **Section 5606**. Roadways that fall under Department of Transportation (DOT) jurisdiction must meet the applicable state DOT retention requirements.

Incorporating GSI into roadways with speed limits equal to or greater than 45 MPH creates additional design challenges due to the variety of high-speed road layouts and purposes. Guidance for identifying infiltration opportunities and constraints based on highway types is found in Table 5607-5.

Table 5607-5: Infiltration Opportunities and Constraints Based on Highway Type

Highway Type	Opportunities for Infiltration	Constraints on Infiltration
Ground-level highways	➔ Infiltration BMPs can be integrated into vegetated conveyances present in the typical cross section. ➔ Wide shoulders and long stretches allow for flexibility in practice selection and siting.	➔ BMPs located in the median and shoulder must allow for errant vehicle recovery. ➔ Future lane expansion or other widening into available space may impact BMP siting. Where lane additions are anticipated, BMP placement in these areas should be avoided. ➔ Shallow slopes may limit routing flexibility.
Ground-level highways with restricted cross sections	➔ Narrow vegetated BMPs or permeable shoulders can be integrated into the right of way (ROW). ➔ Piped conveyance may allow for regional scale BMPs at interchange locations.	➔ Limited space due to adjacent structures. ➔ Construction and maintenance activities may require lane closures. ➔ Geotechnical considerations may be amplified due to proximity to urban structures.
Highways on steep transverse slopes	➔ Infiltration practices can be integrated into areas with shallow slopes or routed to downslope areas. ➔ Piped conveyance may allow for regional scale BMPs at interchange locations.	➔ Creating space for flat-bottomed or level pool basins would tend to increase earthwork requirements. ➔ Construction and maintenance activities may require lane closures. ➔ Underlying soil likely includes compacted fill in some parts of the section. ➔ Stability and erosion concerns are amplified when using surface conveyance on steep slopes.
Highways with steep longitudinal slopes	➔ Piped conveyance may allow for regional scale BMPs at interchange locations.	➔ Creating flat-bottomed or level pool areas for infiltration can require the BMP to be segmented by cutoff walls or berms, increasing cost. This applies to linear systems such as permeable pavement shoulders, vegetated swales, and linear bioretention or infiltration trenches. ➔ Stability and erosion concerns are amplified when using surface conveyance on steep slopes.
Depressed highways	➔ Geotechnical concerns about adjacent infrastructure are lessened because infiltrating surface is at a lower elevation than adjacent slopes and structures.	➔ Limited space due to adjacent urban areas. ➔ Opportunities for vegetated conveyance and dispersion may be limited because of topography. ➔ Groundwater and highway geotechnical concerns are amplified because of installation in low lying areas. ➔ Construction and maintenance activities may require lane closures.
Elevated highways on embankments	➔ Space for infiltration may be available at toe of slope or footing of retaining wall. ➔ Infiltration practices can be integrated into areas with shallow slopes or routed to downslope areas. ➔ Interchange locations likely at lower elevations allowing for routing.	➔ Limited space due to adjacent urban areas. ➔ Geotechnical concerns amplified because of erosion on steep slopes and stability of retaining walls. ➔ Construction and maintenance activities may require lane closures.
Elevated highways on viaducts	➔ Installations may not increase net imperviousness allowing for coordination with existing controls. ➔ Available space possible at ground level. ➔ Interchange locations likely at lower elevations allowing for routing.	➔ No infiltration opportunities on aerial segment. ➔ Geotechnical stability concerns amplified when infiltrating below viaduct columns. ➔ Land ownership may limit areas in which runoff can be managed.

Note: Table 6, Section 2.2.2, Physical Constraints and Project Layout Assessment of Stormwater Infiltration in the Highway Environment: Guidance Manual (2020)

5608

DESIGN CRITERIA FOR CONVEYANCE PRACTICES

5608 DESIGN CRITERIA FOR CONVEYANCE PRACTICES

5608.1 CONVEYANCE PERFORMANCE REQUIREMENTS

A. Introduction

A **stormwater conveyance system** shall be required when the drainage area is 2 acres or more and such that property not reserved or designed for conveying stormwater shall be protected from inundation by providing levels of service stated in **Section 5602**. Additionally, a stormwater conveyance system shall be required when warranted by spread, depth, or other safety concerns per the Urban Drainage Design Manual, Hydraulic Engineering Circular No. 22 (HEC-22), U.S. Department of Transportation Federal Highway Administration. The stormwater conveyance performance requirements may be met with one or a combination of the following **conveyance practices**:

- Overflow Routing
- **Enclosed Pipe System**
- **Open Channel** (**minor drainage system** or **engineered channels**)
- **Natural Channels**

The NOAA **Nested Rainfall Distributions** defined in **Section 5603** shall be used for design of all conveyance features. Each conveyance practice shall be designed to meet the required stormwater level of service and include a designated overflow route to manage flows beyond design capacity. Table 5602-9 in **Section 5602.4** summarizes the stormwater conveyance performance requirements.

B. Application of Hydraulics Calculations

The owner is responsible to provide stormwater conveyance infrastructure which meets the level of service requirements listed in Table 5602-8. The following steps shall be completed to design a stormwater conveyance network (these steps need not be executed in the exact order listed below):

A. **Preserved Stream Identification**. Streams with drainage areas of 20 acres or greater are required to be preserved. Clearly plot the stream centerline of any preserved natural channels and associated required stream setbacks per Table 5604-2.

   - Modifications to preserved streams are not to be made except where natural channel design (Section 5608.5) is followed, and preservation, retention, and detention practices shall be sited upstream of natural channels to the maximum extent possible to preserve the health of the natural channels.
   - If a preserved stream is found to provide insufficient conveyance to meet required levels of service for open channels listed in Table 5602-8, then the open channel shall not be modified and the open channel level of service requirement shall be waived. The prevailing criteria for the open channel shall be to meet the channel crossings and overflow routing requirements, and the site shall be adjusted to meet these criteria.

B. Engineered Site Conveyance. Stormwater conveyance upstream of preserved streams may be comprised of one or a combination of the following elements:

   - Preserved Natural Streams upstream of the minimum requirements of Table 5604-2.
   - Engineered Channels
     - » Channels
     - » Natural Conveyance Channels
     - » Stabilized Channels
   - Enclosed Systems

Once planned, these elements shall be modeled dynamically as a system using either 1D Hydraulic Calculations, 2D Hydraulic Calculations, or a combination of both, as described below.

C. 1D Hydraulic Calculations

The engineer shall use 1D hydraulic calculations when analyzing and designing open channel or pipe conveyance flows. 1D calculations assume that the flow is uniform and steady, and that the velocity, depth, and cross-sectional area of the flow do not change significantly along the length of the channel or pipe. For more complex channel flows where the flow is affected by changes in channel geometry, roughness, and slope, designers may need to use 2D hydraulic calculations as defined in Section 5603. The engineer shall analyze a range of conditions for gravity or pressure flow conditions and reference HEC-22 for calculations.

Any modeling software which meets the calculation requirements below may be used.

Gravity Flow Conditions

Designers commonly use Manning's equation to estimate average flows in pipes and open channels as follows:

Equation 5608-1:

$$Q = \frac{(1.49) * A * (R^{\frac{2}{3}}) * (S^{\frac{1}{2}})}{n}$$

Q = Rate of flow per second (ft^3/s)
A = Cross sectional area of flow (ft^2)
n = Roughness coefficient (see Table 5608-1)
R = Hydraulic radius (R=A/P) (ft)
S = Slope per foot (ft)
P = Wetted perimeter (ft)

For circular storm drains flowing full, Manning's equations becomes:

Equation 5608-2:

$$Q = \left(\frac{0.46}{n}\right) D^{2.67} S_o^{0.5}$$

Q = Rate of flow per second (ft^3)
n = Roughness coefficient (see Table 5608-1)
D = Storm drain diameter (ft)
So = Slope of the energy grade line (ft/ft)

Table 5608-1: Manning's Roughness Coefficient

Type of Channel	n	Type of Channel	n
Closed Conduits		Random Stone	0.020
Reinforced Concrete Pipe (RCP)	0.013	Cement Rubble Masonry	0.025
Reinforced Concrete Elliptical Pipe	0.013	Dry Rubble or Riprap	0.030
Corrugated Metal Pipes (CMPs)		Gravel bottom, side of:	
2 2/3 x 1/2 in Annular or Helical Corrugations unpaved - plain	0.024	Random Stone	0.023
2 2/3 x 1/2 in Annular or Helical Corrugations paved invert	0.021	Riprap	0.033
3 x 1 in Annular or Helical Corrugations unpaved - plain	0.027	Grass (Sod)	0.030
3 x 1 in Annular or Helical Corrugations paved invert	0.023	Riprap	0.035
6 x 2 in Corrugations unpaved - plain	0.033	Grouted Riprap	0.030
6 x 2 in Corrugations paved invert	0.028	Open Channels (Unlined) Excavated or Dredged	
24" diameter and smaller with Helical Corrugations*	0.020	Earth, straight and uniform	0.027
Vitrified Clay Pipes	0.013	Earth, winding and sluggish	0.035
Asbestos Cement Pipe	0.012	Channels, not maintained, weeds and brush uncut	0.090
Open Channels (Lined)		Natural Stream	
Gabions	0.025	Clean stream, straight	0.030
Concrete		Streams with pools, sluggish reaches, heavy underbrush	0.100
Trowl Finish	0.013	Flood plains	
Float Finish	0.015	Grass, no brush	0.030
Unfinished	0.017	With some brush	0.090
Concrete, bottom float finished, with sides of:		Street Curbing	0.014
Dressed Stone	0.017		

* Allowed only when the pipe length between structures is at least 20 pipe diameters

Pressure Flow Conditions

An enclosed pipe system may be designed to operate with surcharge in a pressure flow condition if the following conditions are met:

1. The Hydraulic Grade Line (HGL) must be 0.5 feet below any openings to the ground or street at all locations.
2. Watertight joints capable of withstanding the internal surcharge pressure are used in the construction according to **Section 2600**.
3. Energy losses for bends, transitions, manholes, inlets, and outlets, are used in computing the HGL. Guidance for calculating minor losses in enclosed drainage systems is provided in KDOT's Urban Drainage Manual: **https://www.ksdot.gov/Assets/wwwksdotorg/bureaus/burRoadDesign/drainagemanualsections/Section_7.pdf** or Section 750.4 MoDOT's Engineering Policy Guide: **https://epg.modot.org/index.php?title=750.4_Storm_Sewers#750.4.4_Hydraulic_Design_and_Analysis_of_Storm_Drain_Conduits**
4. Energy methods (Bernoulli's equation) must be used for the computations.

In enclosed pipe system flowing under pressure flow, the energy grade line (EGL) will be above the crown of the pipe. In this case, the Bernoulli equation shall be used to calculate pipe capacity:

Equation 5608-3:

$$\frac{p_1}{\gamma}+\frac{v_1^2}{2g}+z_1=\frac{p_2}{\gamma}+\frac{v_2^2}{2g}+z_2+h_f+h_m$$

p_1/γ = pressure head in the upstream system segment (ft)

$v_1^2/2g$ = velocity head in the upstream system segment (ft)

z_1 = elevation of the system invert in the upstream system segment (ft)

p_2/γ = pressure head in the downstream system segment (ft)

$v_2^2/2g$ = velocity head in the downstream system segment (ft)

z_2 = elevation of the system invert in the downstream system segment (ft)

h_f = friction loss in the downstream system segment (ft)

h_m = minor system losses in the downstream segment (ft)

Pipe friction losses, h_f, may be calculated by the Darcy formula, the Hazen-Williams formula, or the friction slope method.

Darcy Formula:

The most common expression for calculating head loss due to friction is the Darcy formula:

Equation 5608-4:

$$h_f=\frac{f*L*v^2}{D*2g}$$

f = the friction factor, determined from the Moody friction factor chart in **Figure 5608-1**

L = length of pipe (ft)

v = velocity of flow at point of interest in feet per second

D = diameter of pipe (ft)

2g = 64.4 feet per second per second

Hazen-Williams Formula

Another method for finding friction head loss is the Hazen-Williams formula. The Hazen-Williams formula should be used only for turbulent flow. The Hazen-Williams head loss is:

Equation 5608-5:

$$h=\frac{3.022*v^{1.85}*L}{(C^{1.85}*D^{1.165})}$$

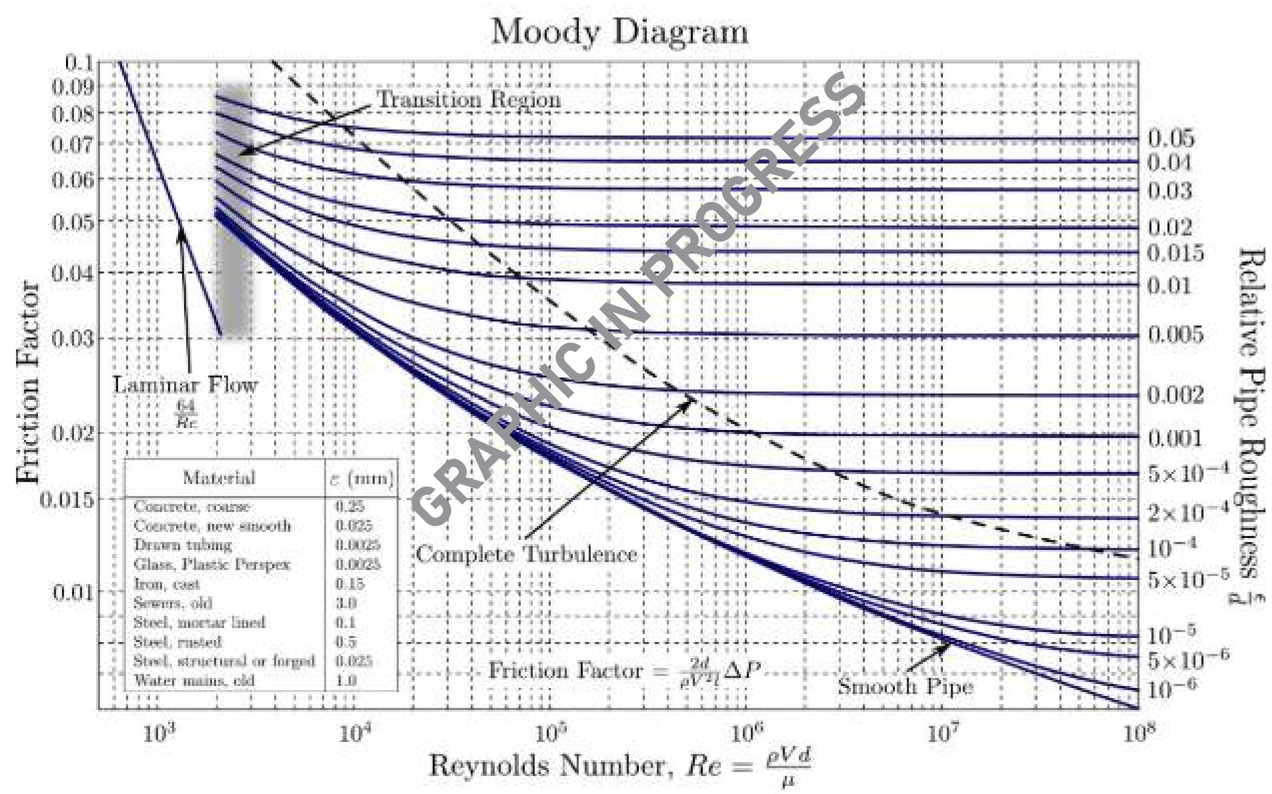
L = length of pipe (ft)

v = velocity of flow at point of interest in feet per second

D = diameter of pipe (ft)

C = Loss coefficient, determined from H-W chart for various pipe materials

Figure 5608-1: Moody Friction Factor Chart



Friction Slope Method

The friction slope method (Equation 5608-6 below) is commonly used to calculate friction head loss in pipes or closed conduits. It assumes that the flow is steady, fully developed, and laminar or turbulent.

Equation 5608-6:

$$h_f=s_f*L=((Q*n)/(1.486*A*R^{\frac{2}{3}}))^2*L$$

h_f = Pipe friction losses (ft)

s_f = Friction slope (ft/ft) which is generally assumed to be equivalent to the slope of the hydraulic grade line

L = Length of pipe (ft)

Q = Rate of flow (ft^3/s)

n = Roughness coefficient (see **Table 5608-1**)

A = Cross sectional area of pipe (ft^2)

R = Hydraulic radius (R=A/P) (ft)

Minor losses, h_m, shall be calculated using Equation 5608-7:

Equation 5608-7:

$$h_m=\frac{k*v^2}{2g}$$

h_m = Minor loss (ft)

k = Minor loss coefficient, as shown in **Table 5608-2**

v = Velocity in pipe

2g = 64.4 ft/s/s

Table 5608-2: Head Loss Coefficients

Condition	k	Condition	k
Manhole, Junction Boxes, and Inlets with Shaped Inverts		Pipe, or Pipe-Arch, Corrugated Metal	
Thru Flow	0.15	Projecting from fill (no headwall)	0.9
Junction	0.4	Headwall or headwall and wingwalls square edge	0.5
Contraction Transition	0.1	Mitered to conform to fill slope, paved or unpaved slope	0.7
Expansion Transition	0.2	Standard end section	0.5
90 Degree Bend	0.4	Beveled edges, 33.7° or 45° bevels	0.2
45 Degree Bend	0.3	Side of slope-tapered inlet	0.2
Culvert Inlets		Box, Reinforced Concrete	
Pipe, Concrete		Headwall parallel to embankment (no wingwalls)	
Projecting from fill, socket end (grove end)	0.2	Square edged on 3 edges	0.5
Projecting from fill, sq. cut end	0.5	Rounded on 3 edges to radius of 1/12 barrel dim. or beveled top edge	0.2
Headwall or headwall and wingwalls socket end of pipe (groove end)	0.2	Wingwalls at 30° to 75° square edged at crown	0.4
Square edge	0.5	Crown edge rounded to radius of 1/12 barrel dimension or beveled top edge	0.2
Round (radius=1/12D)	0.2	Wingwalls at 10° to 25° to barrel - square edged at crown	0.5
Mitered to conform to slope	0.7	Wingwalls parallel (extension of sides) - square edged at crown	0.7
Standard end section	0.5	Side or slope-tapered inlet	0.2
Beveled edges, 33.7° or 45° bevels	0.2		
Side or slope-tapered-tapered inlet	0.2		
Note: When 50 percent of more of the discharge enters the structure from the surface, "k" shall be 1.0.			

A step-by-step procedure for manual calculation of the EGL using the energy loss method is presented in Section 7.5 of the Urban Drainage Design Manual, Hydraulic Engineering Circular No. 22, U.S. Dept. of Transportation Federal Highway Administration.

D. 2D Hydraulic Calculations

Hydraulic modeling using 2D calculations shall follow the requirements listed in **Section 5603.4.F**.

5608.2 DESIGN CRITERIA FOR OVERFLOW ROUTING

Description

An overflow route provides conveyance for large flood events through a site. Because large flood events are relatively infrequent, the overflow route need not follow primary flow paths on the site.

Where to Use

Overflow routes are sited away from buildings, typically in backyards of residential developments and through infrequently used portions of commercial sites.

Design Criteria:

A designated overflow route for runoff generated by the 100-year design storm shall be provided meeting the following requirements:

- Minimum for 2-feet freeboard at all building openings above the 100-year design storm at any point along the drainage system.
- Non-habitable accessory buildings are sometimes provided less protection by local jurisdictional ordinances or policies. Consult local authority for exceptions.
- Property not reserved or designed for conveying stormwater shall also be protected from frequent inundation.
- Areas of high depth or velocity at or near streets and pedestrian paths shall be identified by the Depth-Velocity Flood Danger Level Relationships in **Figure 5608-1** and **Figure 5608-3**. The graph for adults may be used to determine acceptable depth and velocity within the streets while the graph for children may be used to determine acceptable depth and velocity elsewhere in the right-of-way. The intended application of the criteria is to limit 10-year overland flow to the right-of-way only.

Figure 5608-2: Depth-Velocity Flood Danger Level Relationship for Adults

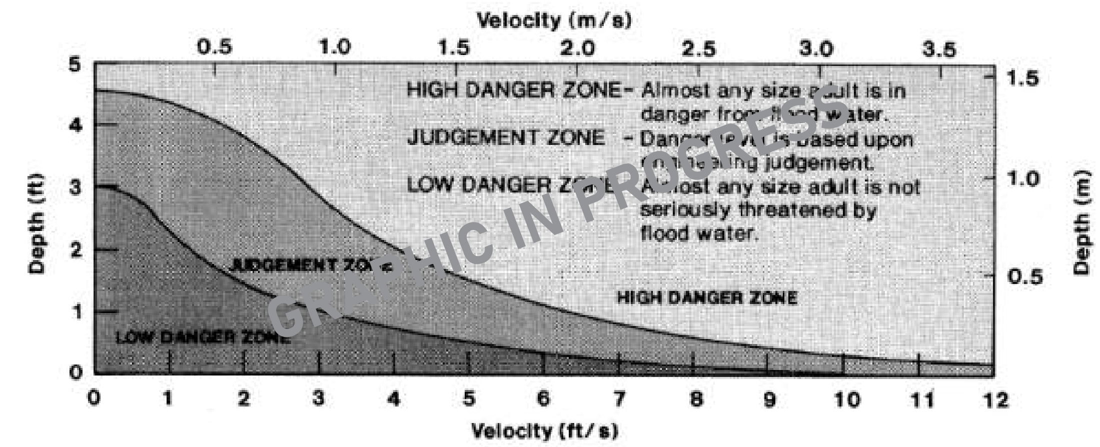
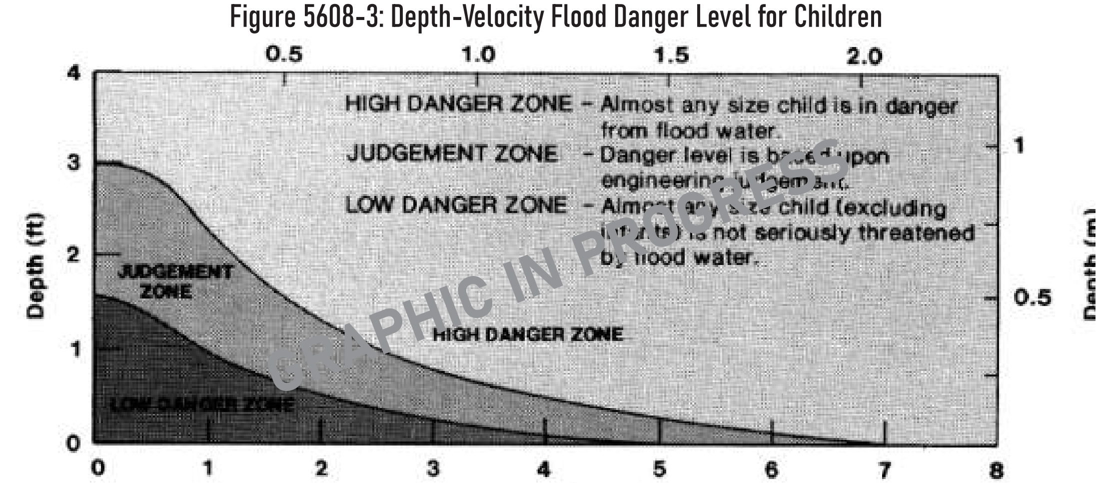


Figure 5608-3: Depth-Velocity Flood Danger Level for Children



5608.3 DESIGN CRITERIA FOR ENCLOSED PIPE SYSTEMS

Description

Enclosed pipe systems convey runoff through a series of inlets, pipes, manholes, and other enclosed hydraulic structures.

Where to Use

The following section presents criteria and design methods for determining the size, slope, cover, location, and angles of enclosed pipe systems.

Considerations

The following are recommendations and considerations for designing enclosed pipe systems.

- Pipes shall be sized according to **Section 5608.1** with adequate capacity to accommodate runoff that will enter the system.
- Where feasible, stormwater pipes should be designed to avoid existing utilities and provide adequate vertical separation as outlined below.

Design Criteria

Minimum Pipe Size and Slopes

The minimum allowable pipe size for an enclosed pipe system is 15 inches. The minimum storm drain flowing velocity for full pipe flow shall be three (3) feet per second. When designing drainage pipes, it is important that the pipes have a minimum slope of 0.4% for proper flow and to prevent blockages. However, in some cases, the available grades may limit the ability to meet the minimum slope requirements, and alternative solutions that use less than the minimum slope can be considered.

Structures and Inverts

- Cover: Minimum depth of cover from the top of the pipe to the finished grade of the ground shall be at least 18 inches, unless accepted by the approving jurisdiction. Common exceptions include a Reinforced Concrete Box (RCB) if rated properly under a paved surface.
- For highway applications, designers typically maintain a minimum cover depth of 3 ft where possible or follow applicable guidelines. Where designs cannot meet these criteria, designers should evaluate the storm drains to determine if they are structurally capable of supporting imposed loads. Refer to **Section 2604** for specific pipe cover requirements for HDPE pipe.
- Minimum Loading Conditions: Refer to **Section 2604**
- Crown: The crown(s) of pipe(s) entering a drainage structure shall be at or above the crown of the pipe exiting from the structure and provide a minimum fall of the invert in the structure of 0.2 feet for straight flow through the structure or 0.5 feet fall for all other types of flow (bends more than 22.5 deflection angle, multiple lines entering, enlargement transition, etc.) through the structure. The desirable minimum fall across the invert is 0.5 feet.
- Vertical Separation between Utilities: the minimum vertical separation between the bottom of storm sewer pipes and the top of other utility crossings is 18" unless otherwise specified by the utility provider or approval jurisdiction.
- Maximum Spacing: the maximum spacing between storm sewer structures shall be 500 feet.
- Pipe Angles: Pipe angles shall be such that the structural integrity of the storm sewer structure is not degraded in a manner that compromises the function, service life, or safety of the structure. Additionally, the angle and direction of pipes entering the storm structure should be carefully considered to ensure that the flow of water is not excessively turbulent, which can increase erosion and reduce the capacity of the structure to hold water. HEC-22 Section 9.1.6 provides additional guidance to estimate energy losses in pipe runs and junctions.
- Storm Drain Structures: Common features and functions of storm drain structure such as inlets, manholes, and junction boxes are outlined in HEC-22 Chapter 8.

Discharge Outfalls

Discharge points from the enclosed pipe systems or engineered channels shall be designed as one of the following. Energy dissipation (**Section 5608.6**) shall be provided for the outfall to be non-erosive.

1. Energy dissipation should be provided at the outlet to reduce velocities per Section 5608.6. Grade control downstream of the outlet and energy dissipater should be provided to prevent undermining of the outfall by future head cuts per **Section 5608.5**. The alignment and location of the outfall and associated energy dissipater and grade control should make a smooth transition into the downstream channel.
2. Tributary outfalls are primary outfalls located on a tributary to a larger downstream segment. Energy dissipation and transition to natural stream flow should take place in the tributary at least one channel width upstream of the confluence per **Section 5608.5**. Grade control in the tributary upstream of the confluence shall be provided if the tributary flow line is higher than the adjoining channel or if future incision of the adjoining channel is anticipated. Tributary outfalls may be used in all situations of tributary flow.
3. Lateral outfalls are small outfalls that discharge from the banks of a natural stream. Outfalls shall be located to enter on a riffle or from the outside of a bend but should generally not enter from the inside of a bend. Outfall pipes shall be oriented perpendicular to the flow of the stream with the invert at or slightly below top of the next downstream riffle. Outfalls shall be flush with or setback from the bank. The bank shall be shaped to provide a smooth transition and protected with reinforced vegetation (preferred) or rip- rap. If the outfall is in a bend, it shall be set back from the existing bank a sufficient distance to account for future meander migration, and the transition shall be graded and reinforced with vegetation. Riprap or hard armor protection should not be used in a bend. Perpendicular outfalls may only be used when the contributing drainage area of the outfall is less than 40% of that in the downstream channel.
4. Edge-of-buffer outfalls are discharge points in the outer half of the riparian buffer that return the discharge to diffused overland flow. Outfalls shall be designed to spread flow and allow overland flow and infiltration to occur. Overland flow shall be directed to run in the outer portion of the buffer parallel to the channel direction to increase length of flow and prevent short-circuiting directly into the stream. Low weirs and berms may be graded to direct flow and encourage short-term ponding. The buffer zone utilized for infiltration shall be maintained in dense, erosion-resistant grasses or grasses reinforced with turf- reinforcing mats designed to withstand the shear stresses of a 10-year storm. Edge-of-buffer outfalls that are part of a system of upland drainage using multiple small, distributed overland swales and ditches instead of pipes may provide significant infiltration and water quality treatment. Edge-of-buffer outfalls shall only be used if each individual outfall can be designed to operate without scour or the formation of gullies.

5608.4 DESIGN CRITERIA FOR OPEN CHANNELS

A. Introduction

Open channels are the preferred means to convey stormwater through a site because they are cost-effective compared to enclosed systems and offer greater resilience to future conditions. They provide an effective means of conveyance in any storm drainage system and cover a wide range of configurations, both naturally-formed and man-made. Design criteria for open channels varies depending on the type of open channel and incorporates differing hydraulic and preservation considerations. This section presents the types of open channels covered in this manual, with definitions of terms contained in **Appendix A**.

B. Minor Drainage System

Description

A **minor drainage system** conveys runoff through open channels in the upper portions of the watershed where there is 2 acres or less of drainage area.

Where to Use

These systems are typically found upstream of enclosed pipe systems, moving runoff in rear and side yards, through and between properties. Minor drainage systems may be well defined or follow more natural overland flow paths on undeveloped topography.

Design Criteria

The following are recommendations and considerations for designing minor drainage systems. Designer shall provide a detail sheet depicting what shall be constructed.

- Size minor drainage system according to Manning's Equation in **Section 5608.1**.
- Conveyance practices in a minor drainage system are typically open channels.
- Minor drainage systems shall be vegetated; a subsurface drainage tile shall be required if the channel slope is less than two percent (2.0%); and the minimum channel slope shall be one percent (1.0%).
- Privately owned open channels, including man-made ditches, swales, and natural channels, shall be properly sized to prevent erosion, repaired and/or reconstructed if unstable.

C. Engineered Channels

The criteria in this section apply to open channels that are not natural (see definition for Natural Channel). Natural channels are covered in **Section 5608.5**.

Description

Engineered channels span a wide array of man-made channels and engineered solutions to naturally-formed channels. They can be constructed to either replace severely degraded existing channels or where no channel previously existed. Engineered channels should be stabilized using vegetative practices to the greatest extent possible, with hard-armoring solutions to be avoided as much as practicable.

Where to Use

Engineered channels are only allowed upstream of existing streams which are to be preserved per **Section 5604.1.A**. Preserved channels are never allowed to be converted to an engineered channel through modification of the existing channel.

Design Considerations

- Engineered channels are the preferred means of engineered stormwater conveyance and should be implemented to the maximum extent possible.
- Designers should consider railings when pedestrians are able to access engineered channels with steep banks greater than 4H:1V adjacent to walkways.

Channels

Swales are vegetated engineered channels which convey stormwater through a site. Swales shall be sized to meet level of service criteria in Table 5602-8.

Natural Conveyance Channels

Natural conveyance swale are the preferred type of engineered channel, as compared to swales and stabilized channels, as they are design to mimic natural channels while also providing required stormwater levels of service. Natural conveyance swales are intended to promote lower velocities and infiltration, and shall be designed to meet the following criteria:

- No greater than 2% longitudinal slope measures from the beginning of the channel to its discharge point
- A minimum of 1.0 foot of freeboard shall be provided between the lowest opening into habitable structures and the energy grade line of flow for the 1% storm.
- Swales shall be designed to accommodate the 10% storm within a designated common tract.
- The entire channel shall be vegetated with native vegetation to promote stormwater quality. Turf grass is not allowed for natural conveyance swales.
- Vegetated swales must be designed to provide required conveyance levels of service without the use of stabilization techniques. This shall be accomplished by designing the channel's geometry (i.e., cross section and longitudinal slope), such that erosive velocities and sheer stresses are not calculated.

Generally, if a natural conveyance swale is used, the swale shall be maintained continuously until it outlets to a stream or other stormwater management facility. Natural Conveyance Swales are considered a pretreatment practice and assist in meeting site runoff reduction requirements as shown in Table 5605-2.

Stabilized Channels

Channel stabilization may only be used to repair existing channels and may not be used to reduce the dimensions or extent of an engineered channel.

Channel stabilization enhances resiliency of channels by preventing erosion and reducing the risk of flooding. Stable channels with healthy vegetation and natural materials can better withstand the impacts of severe weather events, such as heavy rainfall or flooding.

Channel Linings

1. Minimum lining height shall be the 10-year design storm water profile or bankfull, whichever is greater, plus at least a 0.5-foot freeboard.
2. All channel linings, except turf, shall contain provision for relieving back pressures and water entrapment at regular intervals.
3. Lining height on the outside bend of curves shall be increased by:

Equation 5608-8:

$$y = \frac{D}{4}$$

y = Increased vertical height of lining (ft)

D = Depth of design flow (ft)

Increased lining height shall be transitioned from y to zero feet over a minimum of:

a. 30(y) feet downstream from the point of tangency (P.T.)

b. 10(y) feet upstream from the point of curvature (P.C.).

Lining Material

The following types of lining material shall be used to control damage and erosion. All riprap, grouted riprap, and gabion linings as approved by the jurisdiction shall be designed with a filter fabric in conformance with **Section 2605.2.C.2**.

Other types of lining materials not specifically listed below may be used when accepted by the approving jurisdiction.

Concrete lined open channel bottoms are prohibited unless a waiver to this criterion is granted by the approving jurisdiction. Existing concrete-lined channels may be replaced in-kind, but the designer should work with the approval jurisdiction to evaluate the feasibility of converting the system to a natural channel, as outlined in the Restoring Impacted Streams subsection of **Section 5608.5**.

Table 5608-3: Permissible Shear Stresses for Lining Material

Lining Category	Lining Type	Permissible Shear lb/ft^2
General	Erosion Control Blankets	1.55-2.35
	Turf Reinforced Matrix (TRMs):	
	Unvegetated	3.0
	Vegetated	8.0
	Geosynthetic Materials	3.01
	Celluar Containment	8.1
	Woven Paper Net	0.15
	Jut Nut	0.45
	Fiberglass Roving:	
	Single	0.60
	Double	0.85
	Straw with Net	1.45
	Curled Wood Mat	1.55
	Synthetic Mat	2.00
Vegetative	Class A (See Table 5608-4)	3.70
	Class B (See Table 5608-4)	2.10
	Class C (See Table 5608-4)	1.00
	Class D (See Table 5608-4)	0.60
	Class E (See Table 5608-4)	0.35
	12 in	4.00

Table 5608-4: Classification of Vegetal Covers to a Degree of Retardance

Retardance Class	Cover	Condition
A	Weeping Love Grass	Excellent stand, tall (average 30 in)
	Yellow Bluestem Ischaemum	Excellent stand, tall (average 36 in)
B	Kudzu	Very dense growth, uncut
	Bermuda Grass	Good stand, tall (average 12 in)
	Native Grass Mixture: (little bluestem bluestem, blue gamma, and other long and short Midwest grasses)	(Good stand, Unmowed)
	Weeping lovegrass	Good stand, tall (average 12 in)
	Lespedeza sericea	Good stand, not woody, tall (average 19 in)
	Alfalfa	Good stand, uncut (average 11 in)
	Weeping lovegrass	Good stand, unmowed (average 13 in)
	Kudzu	Dense growth, uncut
	Blue Gamma	Good stand, uncut (average 11 in)
C	Crabgrass	Fair stand, uncut (10 to 47 in)
	Bermuda Grass	Good stand, mowed (average 6 in)
	Common Lespedeza	Good stand, uncut (average 11 in)
	Grass – Legume Mixture – summer (orchard grass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (6 to 8 in)
	Centipedegrass	Very dense cover (average 6 in)
	Kentucky Bluegrass	Good stand, headed (6 to 12 in)
D	Bermuda Grass	Good stand, cut to 2.4 in height
	Common Lespedeza	Excellent stand, uncut (average 4.3 in)
	Buffalo Grass	Good stand, uncut (3.2 to 6 in)
	Grass – Legume Mixture – fall, spring (orchard grass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (4 to 5.2 in)
	Lespedeza sericea	After cutting to 2 in height, very good stand before cutting
E	Bermuda grass	Good stand, cut to height 1.6 in
	Bermuda grass	Burned stubble

Note: Covers classified have been tested in experimental channels. Covers were green and generall uniform.

Alignment Changes

Alignment changes for engineered channels shall be achieved by curves having a minimum radius of:

Equation 5608-9:

$$R = V^2 * W/8D$$

R = Minimum radius on centerline (ft)
V = Design velocity of flow in feet per second
W = Width of channel at water surface (ft)
D = Depth of flow (ft)

Side Slopes

Side slopes shall not be steeper than:

- 3 horizontal to 1 vertical for turf lining
- 2.5 horizontal to 1 vertical for all other lining materials, unless a geotechnical analysis indicates a steeper slope can be used.

Vertical walls may be used for structural lining of improved channels when site conditions warrant; subject to the following special requirements:

- Walls shall be designed and constructed to act as retaining walls.
- Adequate provisions shall be made for pedestrian entry/exit from the channel.

Low Flow Channel

When the bottom width of a trapezoidal open channel exceeds eight feet, a low flow channel/invert or subsurface drain shall be provided to convey low flows. Lateral slopes draining to the low flow channel within the bottom of trapezoidal channel shall have a minimum slope of one percent (1%).

Step Pool Stormwater Conveyance Systems

- Step pool conveyance systems (SPCS) can be applied as gully repairs where concentrated stormwater runoff has eroded steep hillslopes approaching streams. This is an engineering solution with basis in natural step pool channel morphology and is a form of grade control.
- On new construction and in retrofit of eroded channels, SPCS can be used in lieu of drop structures, pipes, and weirs to move runoff across the valley hillslope where a natural stream design would not be stable. The SPCS can be designed.
- The technology and design criteria described in Anne Arundel County Bureau of Watershed Protection and Restoration's Design Guidelines for Step Pool Stormwater Conveyance Systems (2022)1 can be adapted to regional and project-specific conditions.

Road Crossings

Description

Road crossings are used to provide safe passage for vehicles and pedestrians where the transportation network intersections the stormwater conveyance system.

Where to Use

- Road crossings are placed where the transportation network intersects an open channel, and allowed practices include culverts and bridges.

Design Considerations

- The placement of road crossings shall be carefully considered to minimize head losses and to the maximum extent possible, shall be placed perpendicular to the direction of stream flow. The number of stream crossings shall be kept to a minimum and placed where the approach has minimal slope.

Design Criteria

Concentrated flow not conveyed in the gutter system shall be conveyed under streets to prevent vehicles from being swept from the roadway in infrequent storms. These crossings may be bridges, culverts, or underground systems. A common practice is to construct a low point in the roadway so that it does not fall on the bridge or culvert. This practice protects the structure from damage in an overflow condition but does not change this requirement. Crossings will be designed to completely convey design flows without street overtopping in accordance with Table 5602-9 in **Section 5602**.

Further, concentrated flow in excess of the minimum design storm may only overtop the roadway if the following conditions are met:

1. The span of the structure opening is less than 20 feet.
2. The peak stormwater runoff from the 100-year design storm is 250 cfs or less unless a guard fence is installed on the downstream side of the roadway.

Such overflow depths at low points in roadways during the 100-year design storm will be limited to 7 inches measured at the high point in the roadway cross section; except that it also shall not exceed 14 inches at the deepest point in the roadway cross section, Depths may be limited where necessary by reverse grading the downstream right of way area, by lengthening the vertical curve of the roadway, by reducing roadway crown, or by similar means. Roadway overtopping depths shall be determined by integrating the broad crested weir formula across the roadway profile. Each incremental flow can be determined by using the formula:

Equation 5608-10:

$$q = C * l * h^{\frac{2}{3}}$$

q = the flow for an increment of profile length (width of flow)

l = the incremental width

C = a flow coefficient that shall not exceed 3.0

h = the average depth of flow at each increment

The total flow Q is the sum of the incremental flows. Depth determinations can be made through an iterative process where successive depths are chosen; Q is calculated for each depth and then compared to the known Q at the overtopping point.

Culverts

Classified as having either entrance or outlet control. Either the inlet opening (entrance control), or friction loss within the culvert or backwater from the downstream system (outlet control) will control the discharge capacity.

- **Inlet Control**. Inlet control occurs when the culvert is hydraulically short (when the culvert is not flowing full) and steep. Flow at the entrance would be critical as the water falls over the brink. If the tailwater covers the culvert completely (i.e., a submerged exit), the culvert will be full at that point, even though the inlet control forces the culvert to be only partially full at the inlet. The transition from partially full to full occurs in a hydraulic jump, the location of which depends on the flow resistance and water levels. If the flow resistance is very high, or if the headwater and tailwater levels are high enough, the jump will occur close to or at the entrance. Design variables for culverts operating under entrance control shall be determined from the FHWA's Hydraulic Design of Highway Culverts (HDS 05).

- **Outlet Control**. If the flow in a culvert is full for its entire length, then the flow is said to be under outlet control. The discharge will be a function of the differences in tailwater and headwater levels, as well as the flow resistance along the barrel length. Design variables for culverts operating under outlet control shall be determined from HDS 05.

Refer to the Federal Highway Administration website for the design variable charts for culverts. Any modeling software which meets the requirements of Section 5608.1 – 1D Hydraulic Calculations can be used to design culverts.

Bridges

Proper evaluation of the velocity, depth, and width of flow requires analyses of the structures and conditions that impact the flow. Boundary flow conditions upstream and downstream from the open channel system must be established. The standard-step backwater method, using the energy equation, can be used to determine the depth, velocity, and width of flow. Major stream obstructions, changes in slope, changes in cross-section, and other flow controls can cause significant energy loss. In these cases, the energy equation does not apply, and the momentum equation must be used to determine the depth, velocity, and width of flow.

5608.5 NATURAL CHANNELS

Description

A **natural channel** is an open channel that is generally naturally occurring and has geomorphological characteristics such as being allowed to meander, having a natural vegetated overbank, and having achieved a state of equilibrium with regard to sediment transfer, erosion, and other geomorphologic factors.

Where to Use

This section sets forth general principles and processes for the protection of natural channels for stormwater conveyance. Unless otherwise provided for by City, State, or Federal law, regulation, or standards, existing natural channels shall be preserved and protected in accordance with this section. Where natural channels are not preserved, the drainage will be handled through systems designed in accordance with **Section 5608.4**.

Design Considerations

- The following are recommendations and considerations for designing natural channels. Designer shall provide a detail sheet depicting what shall be constructed.
- If the natural channel meets the definition of a **stream**, stream preservation & setbacks will need to be provided. Additionally, a stream assessment will be required per **Section 5610**.
- Size channels according to **Section 5608.1**.

A. Stream Preservation & Setbacks

Reference **Section 5604** for requirements on Stream Preservation & Setbacks.

B. In Stream Construction – General Requirements

For all streams with a drainage area greater than 20 acres, a stream assessment shall be conducted in accordance with this section for all construction within the setback zone except for discharge outfalls, unless otherwise directed by the approval jurisdiction.

Energy Management:

The pre-project and post-project hydraulic and energy grade lines for the 1-year, 2-year 10-year, 25-year, 50-year and 100-year design storm flows shall be plotted. The region of a stream where in-stream construction causes a change in these grade lines is considered the zone of influence. The extent of the zone of influence downstream shall be generally limited by energy dissipation and grade control. The upstream limit of the zone may extend a distance beyond the construction as a drawdown or backwater curve. Within the zone of influence, the energy of the flow on the channel will be evaluated for the potential of excessive scour, deposition, initiation of head cuts, or other instability. The use of vegetation to increase bank resistance and minimize increases or abrupt changes in velocities is recommended. Bank or bed stabilization may be required in areas of unavoidable velocity or depth increase. Refer to Section 5608. for design of energy dissipators.

Sediment Transport Continuity:

Sediment transport capacity and continuity shall be demonstrated. A variety of means are applicable depending on the practical availability of data and subject to approval of the jurisdiction. Demonstration may include at least one of the following methods:

- Applied Shear. The minimum post-project applied shear to the bed of the channel in the zone of influence at the 1-year, 10-year, and 25-year ultimate conditions storm shall not be less than 90%, nor greater than 110%, of the minimum pre-project applied shear in the zone, so as to maintain the ability of the channel to transport sediment and to preclude excessive transport. If such shear stresses cannot be maintained, the engineer will evaluate the potential for future sediment removal or maintenance. If standard critical shear stress thresholds for erosion are less than 110% of the pre-project applied shear, a **fluvial geomorphologist** shall determine if a reduced upper limit is necessary to protect the relevant fluvial surfaces from erosion on the streambed, streambank, meander belt, and valley hillslope. This method applies to conditions where proposed or historic land use changes are expected to change runoff response.

Fluvial geomorphic qualifications shall be demonstrated by at least one of the following criteria;

1. Professional with an advanced degree incorporating academic training and research experience in applied fluvial geomorphology, with at least 5 years of experience applying fluvial geomorphic assessments to restoration project evaluations.
2. Licensed design professional with at least 5 years' experience and a clear track record of successfully incorporating fluvial geomorphic principles at the core of their design practice.
3. A professor teaching fluvial geomorphology at an accredited college or university and more than 3 refereed publications in the discipline of applied fluvial geomorphology.
4. Someone working under a professional meeting the requirements above.

- Power Regime. As outlined in Chapter 11 of the USDA's Stream Restoration Design National Engineering Handbook, Rosgen's FLOWSED/POWERSED (2007) calculations may be used to compare the sufficiency of stream corridor capacity and continuity of sediment transport under existing and proposed alterations to land use and stream channel conditions affecting sediment yield; for proposed or historic flow diversions; for sites subject to sustained changes in the daily, seasonal, and/or inter-annual flow regime; and to assess localized areas of channel repatterning at or near stream crossings.

- Numerical Transport Modeling. HEC-RAS 2-D or similarly capable 2-D or 3-D hydraulic model with embedded state equations for sediment transport calculation can be used to compare existing versus proposed sediment transport loads. They shall be retained within 90% to 110% of existing condition, unless the approval jurisdiction determines the existing loads are adverse and a practical reduction (or increase) is more suitable and practical. This method is expensive and data intensive, requiring sediment transport monitoring for calibration, and can be substantially inaccurate absent proper calibration. It is thus typically reserved for application to large rivers with investments in the necessary field measurements and monitoring.

Transitions

- In-stream structures shall be designed to gradually blend into the **natural channel** and provide a smooth transition of both geometry and roughness.

- **Repair of Disturbed Banks**: The side slopes of banks where construction occurs shall be restored with native vegetation in accordance with **Section 5604** as soon as construction is complete. Native vegetation characteristically plays essential roles in streamside and floodplain stability, and if it is removed severe local erosion can occur. It takes time for root development to add the necessary shear strength to the sediment and soil, thus a variety of biodegradable erosion control materials are available to hold the surface together and offer time for root establishment. These materials shall be integrated with native plantings used in soil bioengineering applications using species and stock sizes known to provide adequate bank strength. To provide continuous bank and surface protection, the establishment of vegetation shall be managed and corrected as needed to develop sufficient root coverage before the temporary erosion control materials expire.

- **Hard Armoring**: There may be a need to apply **hard armoring** practices in fully developed areas in cases such as those where structures are in danger of failing. When designing and implementing hard armoring techniques for bank protections, consider several parameters:

- Wave energy and direction: The type and intensity of wave energy and direction can impact the effectiveness and durability of the hard armoring structure. The design should account for the expected wave conditions and direction of the water flow.

- Soil and sediment characteristics: The soil and sediment characteristics of the shoreline or riverbank can impact the stability of the hard armoring structure. The design should consider the soil type, soil permeability, and sediment transport patterns.

- Local ecology and habitat: The use of hard armoring can impact the local ecology and habitat. The design should consider the potential impacts on surrounding habitats, aquatic life, and other wildlife species.

- Regulatory requirements: The design should comply with all applicable regulations and permits.

- Aesthetics: Hard armoring structures can have a significant impact on the aesthetic value of the bank. The design should consider the visual impact of the structure and incorporate elements that blend in with the surrounding environment.

- **Professional Judgment**: Natural channels are complex, variable, and strongly governed by local geology and climate. These standards are based on general guidelines of good practice on typical local streams and may not be optimal or sufficient in all cases. Specific requirements may be increased or waived by the approval jurisdiction if conditions warrant, and decisions should be guided by prudent engineering judgment aided by the perspectives of a qualified fluvial geomorphologist.

C. Stream Assessment

A stream assessment shall be conducted according to **Section 5610.5**.

Figure 5608-4: Above Grade Crossing

D. Culverts, Bridges and Above Grade Crossings

1. Crossings should generally be located on a riffle. If the width of the crossing is large relative to the length of the riffle, then grade control structures shall be provided at the riffles upstream and downstream to isolate the impact of the crossings. If a crossing cannot be made at a riffle, avoid armoring a pool and place at-grade grade control structures at the riffle immediately upstream and downstream of the crossing. Maintain sediment transport continuity and avoid altering the channel cross-section.

2. Realignment of channels to accommodate crossings and their approach should be avoided and minimized as much as possible. Any areas relocated shall have the banks stabilized in accordance with **5608** and shall be included in the reach isolated by upstream and downstream grade control.

3. For bridges the multi-stage channel shape should be maintained and additional area to convey the design flow shall be above the elevation of the bankfull discharge.

4. For multi-cell pipe and culvert crossings that have a cumulative width larger than the bankfull width, those cells wider than the bankfull width shall have a flow line located at the lowest estimated bankfull depth, or a weir wall or other structure upstream of the culvert opening shall be installed with a height to prevent access to the cell during flows less than bankfull flow. The weir wall shall be designed so that the hydraulic efficiency at the 100-year design ultimate conditions storm is not reduced. The designer may also use a low-flow cell as an option. Without these features, the culvert may tend to build up deposits and lose capacity or require frequent maintenance, particularly when crossings are located in sharp bends or streams with high sediment loads.

5. Culverts shall be designed so that there is minimal backwater effect at all flows up to the 25-year storm discharge. Energy management and sediment transport continuity shall be checked.

6. When new and replacement culverts must be embedded below the streambed, such as to promote aquatic organism passage, design shall follow Kansas Department of Transportation (KDOT)'s Hydraulic Design of Embedded Culverts (2017). **https://www.ksdot.gov/Assets/wwwksdotorg/bureaus/KdotLib/2017/KU_16_2_Summary.pdf**

E. Below Grade Stream Crossings

1. Below grade stream crossings primarily include utility pipelines. Crossings should generally be at riffles and grade control structures constructed at the riffle, in addition to or constructed integrally with any encasement of the line the utility may require.

2. If riffle crossing is not feasible, the crossing should be in a pool that is protected by a downstream grade control structure. The top of crossing elevation should be at least two feet below the top of grade control. Crossings under pools should not be armored directly but are protected by downstream grade control.

3. Below grade crossings shall be perpendicular to the stream whenever possible. If a perpendicular crossing is not feasible, the grade control protecting the crossing shall be perpendicular.

4. Constriction or alteration of the pre-existing channel shape shall be avoided. If alteration occurs, sediment transport continuity and energy management shall be verified. Stream banks shall be repaired using vegetative methods whenever possible and the hydraulic roughness of the repaired stream bank should match that of the undisturbed stream banks.

F. Grade Control

1. Where grade control structures are required, they shall be placed in locations where the stream bed profile will support the creation or continuance of a riffle. The flowline of the grade control shall match the existing riffle.

2. Where stream slope is less than 2%, the Newberry-style grade control structure detailed in Figure 56085 is recommended. Structures shall be constructed from durable stone sized using USACE methodology for steep channels (USACE EM 1110-2-1601, page 3-8, Equation 3-5). Rock shall generally comply with USACE gradations as given in (USACE EM 1110-2-1601, Hydraulic

Design of Flood Control Channels, Chapter 3). Shotrock with sufficient fines to fill voids may be used. The use of filter fabric and uniform gradations of stone are discouraged in stream beds.

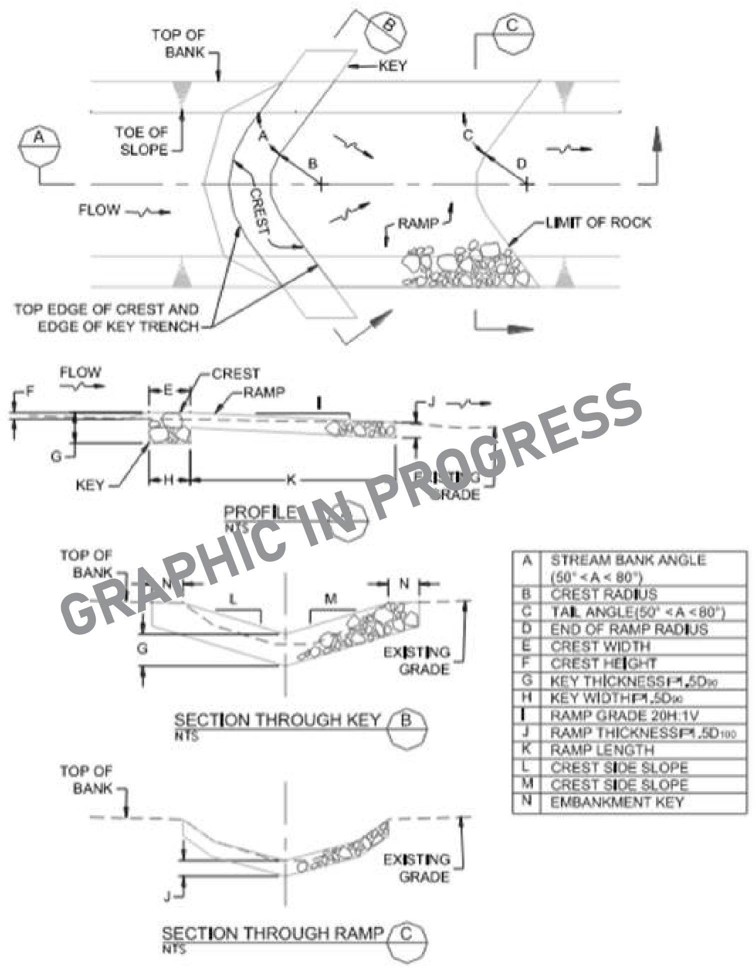
3. Where grades are in excess of 2%, low-drop step structures should be used (USACE EM 1110-2-1601).
4. Alternate styles of grade control may be accepted by the approving jurisdiction. Guidance for grade control design is given in Thomas et.al.
5. Construction of new grade controls structures may be waived by the approving jurisdiction if it is determined that existing riffles are adequate to prevent or retard advancing head cuts, or if it is preferable to accept the risk of future head cut than to further disturb the channel.
6. When grade control is not part of a larger project, energy management and sediment continuity checks are not required.

Floodplain Modifications

No fill shall be placed within the floodway, where FEMA maps have established one, nor should fill be placed within the designated setback zone unless approved by the approval jurisdiction. In areas where no FEMA map has been established, no fill shall be placed within bank limits. Fill placed outside these limits shall not cause a rise in the floodplain of the 100-year ultimate conditions storm beyond the limits of the property controlled by the developer, unless authorized by the approval jurisdiction. Any change in topography within floodway and/or floodplain designated as a special flood hazard area by FEMA shall conform to FEMA and jurisdiction floodplain management requirements.

Compensatory Storage: Fill within the Area of Special Flood Hazard or the Area of Future Conditions Flood Hazard shall result in no net loss of the existing floodplain storage. The volume of the loss of floodwater storage due to filling in the Area of Special Flood Hazard or in the Future Conditions Flood Hazard Area shall be offset by providing an equal volume of flood storage by excavation or other compensatory measures at or adjacent to the development site. Alternatively, the engineer may provide

Figure 5608-5: Grade Control Structure



Notes

1. The depth of key trench shall be a minimum of 1.5 D90.The crest shall slope downward from the stream bank to the center of the structure to focus the flow to the channel center. The tail ramp is generally sloped at 20 horizontal to 1 vertical and dissipates energy gradually over it length. The upstream face is not perpendicular to the flow but has an upstream oriented "V" or arch shape in plan form.
2. For item A, Stream Bank Angle, and item C Tail Angle, the lower end of the range should be used for softer soils.
3. For items L and M, crest angle, the typical range is 5 to 1 to 10 to 1.

a model showing that this is not necessary for the site and that the development is not providing a rise.

G. Bank Stabilization Projects

1. Bank stabilization projects shall be evaluated by a professional geotechnical engineer.
2. **Applicability**: Bank stabilization projects should generally be limited to cases where existing buildings or infrastructure face significant property damage or safety issues. Projects to stabilize banks to facilitate reductions in setback widths for new construction should be avoided.
3. **Before Stabilization**: Prior to stabilization, the causes of the instability should be considered, including the stream's current phase of channel evolution (Interagency, 2001, Chapter 7) and direction of meander migration. Stabilization may be unnecessary if a channel has ceased incision and widening and is in the process of deposition and restoration. If stability issues appear widespread or complex, a systematic evaluation of the stream system by professionals with expertise in river engineering and fluvial geomorphology (as defined in **Section 5608.5.B)** may be justified.
4. For geotechnical issues, a geotechnical engineer shall evaluate the slope stability. Geotechnical designs shall provide for a 1.5 factor of safety (ratio of theoretical resisting forces to driving forces) against slope failure where it would endanger buildings, roadways, or other infrastructure, unless a lower factor of safety is accepted by the approving jurisdiction.
5. **Design Life**: Bank stability projects should have a design life greater than the useful life of the facility being protected, or a life cycle cost analyses shall be performed that considers replacement and repair over the entire protection period. Responsible parties for future maintenance should be identified.
6. **Stabilization**: Stabilization should begin and end at stable locations along the bank. Bank stabilization should be limited to areas of potential erosion and is rarely required on the inside of bends. For long projects, stabilization may alternate from side to side and is rarely necessary across an entire cross section.
   - » The existing cross section should be mimicked to the extent practical and need not be planar or uniform over the entire length. Grade control shall be provided at the riffle both upstream and downstream of the stabilization to isolate it from the surrounding stream and protect the foundation from undercutting. Control at intermediate points for longer projects may also be required. Energy management and sediment transport continuity shall be checked, and energy dissipation provided, if necessary, per Section 5608.6.
7. **Hard-Armor Projects**: "Hard-Armor" projects are those projects that use riprap, placed stone, gabions, retaining walls, or other rigid structures to provide geotechnical and fluvial stability. Such projects shall be designed in accordance with EM 1110-2-1205 (USACE, 1989), EM1110-2-1601 (USACE, 1994), or HEC-11 (FHWA 1989). Materials shall be sized to prevent dislodgement in the 100-year design storm. Gradations should comply with USACE or FHWA recommendations. Stones should be placed to maintain roughness and variations. All material shall be well placed to ensure interlock and stability. Materials shall be keyed into the bed and banks with adequate allowance for scour along the toe and the structure should have adequate foundation. Vertical walls should be avoided when possible as they tend to concentrate scour at their toe and are typically smoother than the natural channel.
8. **Soil Bioengineering**: Soil bioengineering involves the use of living vegetation in combination with soil reinforcing agents such as geogrids to provide bank stabilization by increasing soil shear resistance, dewatering saturated soils, and by reducing local shear stresses through increased hydraulic roughness.
9. Bio-engineering projects shall be designed in accordance with the principles of NRCS (1996) and Gray and Sotir (1996). Designs will be tailored to the urban environment by consideration of the requirement for immediate functionality upon construction, the extreme variability and high shear stress of urban flows and the availability of mechanized equipment and skilled operators.
10. Selection of plants and specifications for planting methods and soil amendments shall be prepared by a professional competent in the biological and stabilization properties of plants. Refer to **Appendix E** for planting criteria.
11. Plants selected shall be appropriate to local conditions and shall be native varieties to the greatest extent practical. Evaluation of local conditions includes assessment of site microclimate, bank slope, soil composition, strength and fertility, type and condition of existing vegetation, proximity to existing infrastructure, soil moisture conditions and likelihood of wildlife predation. Engineering factors influencing plant selection include frequency, height and duration of inundation, near-bank shear stress, size, and volume of bed load as well as depth and frequency of scour.
12. Plants may be either locally harvested or purchased from commercial nurseries. When harvesting, no more than 10% of a given stand may be removed and no plant on the state rare or endangered species list may be harvested or damaged in harvesting operations. Plant material grown in the MARC region is adapted to local climatic conditions and is preferred over more remote sources. Some species such as red maple are particularly sensitive to locale and may only be used if locally available. Seed, plant plugs, rhizomes, whips, live stakes, bare root and container stock may be used. Turf grasses, noxious or invasive species shall not be used. A variety of plant species shall be used to provide greater reliability to a design. For critical functions such as protection from toe scour a minimum of three species should generally be employed.
13. Soil bioengineering methods are properly applied in the context of a relatively stable stream system, and relevant general requirements for all stream bank stabilization projects given in this section apply to bio-engineered projects Soil bioengineering alone is not appropriate when the zone of weakness lies below the

root zone of the plantings, or when rapid drawdown can occur, such as in a spillway or dam embankment.

14. Composite Methods: Composite methods are those which employ both hard armor and soil bioengineering. Typically, armor for toe protection in critical locations is provided, with soil-bioengineering for the remainder. Design principles for both hard armor and soil-bioengineering shall be observed as appropriate.

15. In-stream Stability Structures: In-stream structures are used to focus flow, control grade, dissipate energy and selectively lower near-bank stress. Stream barbs, weirs, guide vanes, vegetative sills, longitudinal peak stone, and grade controls are among the more commonly used in-stream structures. When constructed of natural material such as rock, such structures also create aquatic habitat. They may be used alone or in combination with hard armor, bioengineering or composite methods. In-stream structure design is a river engineering practice and is beyond the scope of this standard.

H. Restoring Impacted Streams

Restoration of urban streams is defined as the re-establishment of natural channel geometry, materials, and vegetative setbacks with the intent of reconstituting natural geometry and functions that have been disturbed or eliminated. Successful design is data-intensive and requires an interdisciplinary approach. This section provides guidance for stream restoration. Any activities near an existing stream should evaluate the stream health using the NRCS Stream Visual Assessment Protocol (2009) to establish pre- and post-construction stream health. This protocol is developed for relatively small streams, be they perennial or intermittent.

Artificially incised drainageways (as determined by a fluvial geomorphologist meeting the requirements of **Section 5608.5.B**) that have already experienced significant erosion from downcutting are to be addressed differently than streams that are not degraded in that manner. Restoration of these types of drainageways requires the following improvements:

- **Eroded or Incised Channels**: Eroded, incised channels, if possible, shall not be stabilized in a manner that retains the incised geometry with steep side banks. Solutions shall utilize vegetated overbank benches adjacent to the base flow channel to allow high flows to spread out and dissipate energy.

- **Priority 1 Restoration**: Priority 1 Restoration shall raise the channel invert up to its historic condition and encourage flows greater than the geomorphic bankfull flow to spread out onto a vegetated floodplain or flood bench, avoiding deep, concentrated flood flows within the channel where possible. This may characteristically include grade control structures to raise the channel invert and to establish a flatter equilibrium slope. This design approach requires flood event modeling (Table 5602-9, **Section 5602**) to confirm raising the bankfull flow and alluvial floodplain flow profiles will not adversely affect the existing flood protection level of service (FPLOS) of offsite assets, real estate, or other private and public infrastructure absent permitting approvals to do so. This criterion presumes the regulations require public and direct notice to affected owners, and either their concurrence of the effects or acquisition of the affected properties prior to permit issuance. Otherwise, Priority 1 Restoration is recommended not to be accepted by the approving jurisdiction. The designer must consider both restoration practices and regulatory requirements. For example, they should balance the need to restore the habitat with the potential for regulatory issues such as a requirement to restore at a higher ratio than existing conditions or potential changes to the FEMA floodplain.

- **Priority 2 Restoration**: In cases where Priority 1 Restoration is not feasible or permittable, Priority 2 Restoration takes precedence. This entails retaining the existing channel bottom elevation and excavating a lower flood bench to its bankfull stage. It is a common solution for incised drainage networks in developed landscapes. In some cases, cost, risk, and functional benefits can be optimized by conducting a Priority 2 Restoration with a moderately elevated streambed and a shallower excavated flood bench. Flood studies are required . As with Priority 1, Priority 2 Restoration requires careful provision of grade control, which may need to be structural.

- **Engineered Channels**: For incised channels where lateral constraints and vertical flood limits preclude either Priority 1 or 2 Restoration, engineered solutions can be considered. These are described in **Section 5608.4.C**.

In some cases, channel impairment does not involve incision and can be due to excessive sedimentation from unnaturally high sediment yields upstream, and/or excessive hydraulic loads over bedrock channels that prevent downcutting. The system tends to erode on the channel and valley margins, widening rather than deepening the system. In other cases, incision has historically occurred and progressed to a point of equilibrium along its longitudinal profile but still has an under-dimensioned flood bench leading to serial bank collapses over time until floodplain width achieves equilibrium. In such cases, grade control measures are less important than providing the system with a sufficiently wide floodplain.

In all cases, careful consideration shall be given not only to the flood bench dimension, but also to preserving and sustaining the proper bankfull channel pattern and dimension, as it is also a keystone design variable. Peak flow accommodation should occur over the flood bench part of the conveyance, and the flood bench is the enlargeable feature.

The bankfull channel pattern and dimension is conditioned by the sum effect of common flows that, in aggregate carry most of the overall annual sediment load. So, the circumstances for considering adjusting the bankfull channel are typically when the flow regime is altered such that the annual average flow is on a sustained trend of change. Common scenarios involving a need to change bankfull dimension include artificial flow diversions across watersheds and aquifers for irrigation, flow augmentation from wastewater effluent, and flow abstraction for water supply. If climate change is affecting storm intensification and/or urban hydromodification are altering the peaks and troughs of daily flow variability but not shifting average annual flow volumes, then the solution is likely to retain natural bankfull conditions and require only floodplain modification.

I. Comprehensive Stream Management

The standards set forth in preceding sections provide a moderate degree of mitigation for potential damage from individual construction projects in streams. For more sensitive streams or to obtain a greater degree of protection, jurisdictions may elect to implement comprehensive strategies for stream management. Such strategies should be based on specific investigations of the streams and watersheds in the jurisdiction and consider local geology, geography, climate, and ecology. Strategies may include stream setbacks (see **Section 5604**), hydrology controls, and comprehensive grade control. Detailed requirements for such studies and strategies are beyond the scope of this standard and should be developed in consultation with professionals competent in river engineering and fluvial geomorphology. Qualifications for a fluvial geomorphologist are outlined in **Section 5608.5.B**. The following general recommendations may be considered:

Hydrology Controls for Channel Protection:

Channels respond to changes in flow volumes and recurrence by altering width, depth, velocity, suspended load, meander radius, wavelength and pool and riffle. Avoiding significant changes in flow volume and recurrence should reduce the likelihood of major changes in stream form. Volume control may include practices that encourage infiltration, evapotranspiration, and short-term detention or retention. A successful strategy would require:

Limitations on volume, duration and magnitude of post development discharges at a number of discharge points, including common storms such as the 1-year storm (or the first 0.5 to 2.0 inches of rainfall).

The tail of hydrographs would need to mimic groundwater base flow.

The cumulative effect of multiple detention/retention structures on duration of high flows would be considered.

The impact of large impoundments or retention lakes on trapping sediment and interrupting sediment transport would be considered.

Volume control for channel protection would likely require significantly different control requirements than traditional detention practices that focusesd primarily on flood control from extreme events.

Grade Control

In watersheds subject to deep, rapid, and extensive incision or downcutting, a comprehensive program of controlling bed elevation (grade control) may be the most practical method of preserving stream function and avoiding future bank stability concerns. Streams with easily eroded soils and lacking in shallow bedrock are highly susceptible to extensive degradation. Existing and proposed crossing points such as culverts, bridges, and encased underground utilities should be incorporated into the grade control program. These items are jointly accessible for construction activities without disturbing more pristine sections of creeks, and the crossings themselves benefit from grade control measures that can also serve as counters against pile scour and undermining of supports and culverts. Selection of grade elevations would be based on historical data, flooding or space constraints, restoration of wetlands and streambank hydrology, channel depths, and other relevant data.

5608.6 ENERGY MANAGEMENT

Description

Under many circumstances, discharges from enclosed pipe systems and open channels cause erosion problems. To mitigate this erosion, discharge energy can be dissipated prior to release downstream.

Where to Use

Energy management shall be used where there is a need to dissipate the energy of stormwater flow from enclosed pipe systems and open channels.

Design Considerations

Energy Dissipator Design Procedure

Energy dissipator design structures shall be designed according to the Federal Highway Administration's Hydraulic Engineering Circular No. 14 (HEC-14) Hydraulic Design of Energy Dissipators for Culverts and Channels. The designer should treat the culvert, energy dissipator, and channel protection designs as an integrated system. Energy dissipators can change culvert performance and channel protection requirements. Some debris-control structures represent losses not normally considered in the culvert design procedure. Velocity can be increased or reduced by changes in the culvert design. Downstream channel conditions (velocity, depth, and channel stability) are important considerations in energy dissipator design. A combination of dissipator and channel protection may be used. The designer should apply the following design procedure to each respective stormwater management feature and its associated structure at a time.

1. Identify Design Data
   - » Culvert Data
   - » Transition Data
   - » Channel Data
   - » Allowable Scour Estimate
   - » Stability Assessment
2. **Evaluate Velocities**. Compute culvert or chute exit velocity, V_o, using the Continuity Equation below and compare with downstream channel velocity, V_n. For more guidance, refer to HEC-14 Chapter 3. If the exit velocity and flow depth approximate the natural flow condition in the downstream channel, the culvert design is acceptable. If the exit velocity is moderately higher, the designer can evaluate reducing velocity within the barrel or chute (see HEC-14 Chapter 3) or reducing the velocity with a scour hole (step 3). Another option is to modify the culvert or chute (channel) design such that the outlet conditions are mitigated. If the velocity is substantially higher and/or the scour hole from step 3 is unacceptable, the designer should evaluate energy dissipators (step 4). Definition of the terms "approximately equal," "moderately higher," and "substantially higher" is relative to site-specific concerns such as sensitivity of the site and the consequences of failure. However, as rough guidelines that should be re-evaluated on a site-specific basis, the ranges of less than 10 percent, between 10 and 30 percent, and greater than 30 percent, respectively, may be used.

Equation 5608-11:

$$V_o = Q / A$$

V_o = Exit velocity (ft/s)
Q = Discharge (cfs)
A = Flow area (sq. ft.)

3. **Evaluate Outlet Scour Hole**. Compute the outlet scour hole dimensions using the procedures in HEC-14 Chapter 5. If the size of the scour hole is acceptable, the designer should document the size of the expected scour hole for maintenance and note the monitoring requirements. If the size of the scour hole is excessive, the designer should evaluate energy dissipators (step 4).
4. **Design Alternative Energy Dissipators**

➔ Design one or more of the energy dissipators that substantially satisfy the design criteria. The dissipators fall into two general groups based on Froude Number (Fr):

a. Fr < 3, most designs are in this group

b. Fr > 3, tumbling flow, USBR Type III stilling basin, USBR Type IV stilling basin, SAF stilling basin, and USBR Type VI impact basin. Refer to the United States Bureau of Reclamation's (USBR) Engineering Monograph No. 25 for the Hydraulic Design of Stilling Basins.

   ➔ Debris, tailwater channel conditions, site conditions, and cost must also be considered in selecting alternative designs.

5. **Select Energy Dissipators**. Compare the design alternatives and select the dissipator that has the best combination of cost and velocity reduction. Each situation is unique, and the exercise of engineering judgment will always be necessary. The designer should document the alternatives considered.

Energy Management Structures

The outfall of all stormwater systems shall be designed so that the exiting velocities do not cause erosion downstream. To mitigate erosion, discharge energy can be dissipated prior to release downstream using energy management structures. For some sites, appropriate energy dissipation using an energy management structure may be achieved by design of a flow transition (HEC-14, Chapter 4), anticipating an acceptable scour hole (HEC-14, Chapter 5), and/or allowing for a hydraulic jump given sufficient tailwater (HEC-14, Chapter 6).

Energy Management Structures include:

- ➔ Internal Dissipators (HEC-14, Chapter 7)
- ➔ Stilling Basins (HEC-14, Chapter 8 & USBR Engineering Monograph No. 25)
- ➔ Streambed Level Dissipators (HEC-14, Chapter 9)
- ➔ Riprap Basins and Aprons (HEC-14, Chapter 10 and Section 5608.5.A.3)
- ➔ Drop Structures (HEC-14, Chapter 11)
- ➔ Stilling Wells (HEC-14, Chapter 12)

Energy management structures shall be designed according to the criteria and procedures defined in HEC-14. Table 5608-5 below from HEC-14 shall be used in conjunction with the steps discussed in **Section 5606.2** to choose the appropriate energy dissipator.

Riprap Stone

Riprap stone shall conform to gradation requirements as outlined in the Kansas Department of Transportation's (KDOT) Section 1114 Stone for Riprap, Ditch Lining and Other Miscellaneous Uses for projects in Kansas and the Missouri Department of Transportation's (MoDOT) Section 750.6 Erosion Control and Energy Dissipation for projects in Missouri.

Table 5608-8: Energy Dissipators and Limitations from HEC-14

Chapter	Dissipator Type	Froude Number[7] (Fr)	Allowable Debris[1]			Tailwater (TW)
			Silt/Sand	Boulders	Floating	
4	Flow Transitions	N/A	H	H	H	Desirable
5	Scour Hole	N/A	H	H	H	Desirable
6	Hydraulic Jump	> 1	H	H	H	Required
7	Tumbling Flow[2]	> 1	M	L	L	Not Needed
7	Increased Resistance[3]	N/A	M	L	L	Not Needed
7	USBR Type IX baffled apron	< 1	M	L	L	Not Needed
7	Broken-back culvert	> 1	M	L	L	Desirable
7	Outlet weir	2 to 7	M	L	M	Not Needed
7	Outlet drop/ weir	3.5 to 6	M	L	M	Not Needed
8	USBR Type III Stilling Basin	4.5 to 17	M	L	M	Required
8	USBR Type IV Stilling Basin	2.5 to 4.5	M	L	M	Required
8	SAF Stilling Basin	1.7 to 17	M	L	M	Required
9	CSU Rigid Boundary Basin	< 3	M	L	M	Not Needed
9	Contra Costa Basin	< 3	H	M	M	< 0.5D
9	Hook Basin	1.8 to 3	H	M	M	Not Needed
9	USBR Type VI Impact Basin[4]	N/A	M	L	L	Desirable
10	Riprap Basin	< 3	H	H	H	Not Needed
10	Riprap Apron[8]	N/A	H	H	H	Not Needed
11	Straight Drop Structure[5]	< 1	H	L	M	Required
11	Box Inlet Drop Structure[6]	< 1	H	L	M	Required
12	USACE Stilling Well	N/A	M	L	N	Desirable

[1]Debris Notes: N = none, L = low, M = moderate, H = heavy

[2]Bed slope must be in the range 4% < So < 25%

[3]Check headwater for outlet control

[4]Discharge, Q < 400 cfs and Velocity, V < 50 ft/s

[5]Drop < 15 ft

[6]Drop < 12 ft

[7]At release point from culvert or channel

[8]Culvert rise less than or equal to 60 in

N/A = not applicable

5609

OPERATIONS & MAINTENANCE REQUIREMENTS

NOTE: FORMATTING IS NOT COMPLETED ON THIS SECTION

5609 Operation & Maintenance Requirements

Stormwater infrastructure, whether green or gray, is a functional utility that serves the general public. Like all other infrastructure, stormwater systems require regular inspection, operation, and maintenance to maximize the life of the asset.

5609.1 Planning for Operations & Maintenance

Designs shall consider the operations and maintenance needs for the stormwater drainage system relative to the Owner's capacity and funding mechanism from the inception of the project through the design life of the asset. Maintenance responsibility may differ throughout the project's lifecycle from when construction starts through the full establishment of vegetation, if applicable. During the planning phase of the project, the designer shall identify the stormwater components requiring inspection and maintenance, the expected inspection and maintenance tasks and frequencies, and the party responsible for maintenance using **KC Compliance Calculator** and submit with the Stormwater Concept Analysis defined in **Section 5610.** The following information must be provided:

1. Define all applicable components of the storm drainage system design.
    - Preserved Natural Areas
    - Restored Natural Areas
    - Retention & Detention Practices
    - Collection Practices
    - Conveyance Practices

2. Define typical maintenance tasks and frequencies for the project-specific design. Define maintenance responsible party for each task.

3. Define entity(ies) responsible for the maintenance during the following time periods to the best available information at the time. This form shall be updated with subsequent plan submittals.
    - During Construction: define whether Owner, Contractor, or Subcontractor(s) are responsible for maintenance during construction. List the names and contact information of the responsible parties as well as anticipated construction timeline (month and year)
    - Warranty and/or Vegetation Establishment Period (Years 1-3): whether Owner, Contractor, or Subcontractor(s) are responsible for maintenance during the vegetation establishment period. Confirm anticipated vegetation install start and end times are within appropriate planting windows.
    - Long-Term Owner (Post-Warranty Period): define who is responsible for long-term operations and maintenance of each component of the storm drainage system, whether it is the property owner, the local municipality, an home-owners association (HOA), or other. Describe the source of funding (i.e. utility fee, HOA, owner cost, etc.) and the mechanism (i.e. municipality, contracted service, owner-managed, etc.) of the long-term owner to maintain the stormwater drainage system

5609.2 Maintenance Manual

Designer shall develop a project and/or site-specific maintenance manual to be submitted and recorded with the deed or plat for the property. The maintenance manual shall define the following, at a minimum:

1. **Site map**: identifying all storm drainage system components listed below. Each component shall have a unique identifier.
    - Natural Areas of preservation or restoration
    - Preserved Trees
    - New Trees
    - Retention Practices
    - Detention Practices
    - Conveyance practices
2. **Retention & Detention practice figure**(s): detailed figures for each retention/detention practice identifying all GSI components.
3. **Typical maintenance tasks and frequencies**: identify regular inspection and maintenance tasks and recommended frequencies for each stormwater management practice and applicable components (see Sections 5609.4, 5609.5 and 5609.6). Additional detailed guidance by applicable GSI component is also provided in 5609.7.
4. **Standard inspection forms**: provide standard forms for inspection of all stormwater management practices. The Site Activity Plan in Appendix H may be used to develop standard forms based on frequency of maintenance tasks.

5609.3 Access & Easements

When required by the approving jurisdiction, a permanent easement shall be provided for all storm drainage system components to provide access for inspection and maintenance that are located outside of public right-of-way. The following are recommendations for specific components of the stormwater management system:

A. Easements for Enclosed Pipe Systems

- Easements shall be centered on the pipe when able. In instances where the easement is not able to be centered on the pipe or conveyance structure (such as a nearby building), additional easement area shall be provided to meet the minimum width requirement as space allows.
- Easement widths shall be equal to the outside width of the pipe or conveyance structure plus a 5-foot buffer extending from the outside edge of the pipe or structure on each side. Easement widths shall not be less than 15 feet in total width.
- Wider easements may be required when other utilities are located within the same easement and/or when depth of cover is greater than 4 feet.
- Temporary construction easements of sufficient width to provide access for construction shall be acquired when the proposed work is outside of the owner's property.

B. Easements for Engineered Channels

- Easements shall be as wide as the top of bank width; plus 10 feet on each side.
- Easements shall be continuous between street rights-of-way. When an engineered channel begins or ends at a point other than the right-of-way of a street, a 15-foot or wider easement graded so as to permit access by maintenance equipment shall be dedicated from the end of the channel to a street right-of-way.
- Easements shall be required for engineered channels between private lots that collect stormwater runoff from two or more lots.
- Engineered channels that are located wholly within the street right-of-way do not require an easement. Engineered channels located only partly in street right-of-way shall have a dedicated easement from the street right-of-way extending to 5 feet outside of the top of the outside bank of the channel.

C. Retention & Detention Practices

- Easements shall cover the entire storage footprint of the GSI practice plus an additional 10 feet.
- Easements shall be continuous between street rights-of-way. When a retention or detention practice does not abut the right-of-way of a street, a 15-foot or wider easement graded so as to permit access by maintenance equipment shall be dedicated from the edge of the practice to the street right-of-way.
- Easements shall extend over all GSI components required for the operation of the practice including but not limited to inlets, energy dissipation & pretreatment, area protection, piping, outlets, and perimeter landscaping. When GSI components are located and/or extend outside the GSI storage footprint, easement shall extend over the components to the outside extents of the components plus a 5-foot buffer, or a minimum 15 feet.

5609.4 Typical Maintenance Tasks & Frequencies

The following table summarizes the most common inspection and maintenance tasks, relevant storm drainage system components to which each task may apply and recommended typical frequencies for completion. Each task is discussed in additional detail in the Section 5609.6. Frequency of maintenance is highly dependent on the individual site, surrounding area, and weather conditions. Maintenance frequencies may need to be adjusted to maintain the required service level of performance and to accommodate all external factors. The typical frequencies listed are intended to be used as guidance only, and do not take precedence over the service levels of performance.

Figure 5609-1: Storm Drainage System Typical Maintenance Tasks & Frequencies

Maintenance Tasks	Preservation/ Restoration of Natural Areas	Retention & Detention Practices	Collection Practices	Conveyance Practices
Inspect for Standing Water	Monthly	Monthly	Monthly	Monthly
Inspect Structural Conditions	N/A	Monthly	Monthly	Monthly
Inspect Health & Appearance of Vegetation	Monthly	Monthly	N/A	N/A
Trash & Debris Removal	Bi-weekly	Bi-weekly	Monthly	Monthly
Sediment Removal	Bi-weekly	Bi-weekly	Semi-Annually	Semi-Annually
Clear Stormwater Flow Paths	Monthly	Monthly	Monthly	Monthly
Repair Erosion & Material Settlement	As Needed	As Needed	As Needed	As Needed
Pest & Disease Control	Monthly	Monthly	N/A	N/A
Prune Plants	N/A	As-Needed	N/A	N/A
Remove & Replace Dead Plants	As-Needed	As-Needed	N/A	N/A
Invasive Species and Weed Removal	Monthly	Monthly	N/A	N/A
Maintain Turf Grass Lawn	N/A	Weekly	N/A	Weekly
Refresh Mulch Areas	N/A	Semi-Annually	N/A	N/A

5609.5 Traditional Collection & Conveyance Practice Maintenance Tasks

Traditional "gray" stormwater infrastructure requires regular inspection and maintenance to maintain capacity and performance of the system long-term.

A. Inspect for Standing Water

During every site visit, inspect for standing water and mosquito larvae

- Inspect site 48-hours after a large rainfall event of 3-inches or more in a 24-hour period

B. Inspect Structural Conditions

Report to the appropriate authority any observation of:

- Damaged or broken concrete curbing
- Uneven or sinking pavement or curbing around structures
- Loose or damaged structures, grates, access openings, end sections, headwalls, or other appurtenances

(Photo placeholder)

C. Trash & Debris Removal

- Trash and debris may impede flow of stormwater to inlets and clog conveyance systems
- For open systems or trash and debris removal at the surface, remove by hand or with lightweight equipment (litter pickers)
- For enclosed systems, clean with jet-vacuum as needed to remove trash and debris build-up

(Photo placeholder)

D. Sediment Removal

- Sediment may impede flow of stormwater to inlets
- For open systems, use a shovel to remove sediment buildup or blockages
- For enclosed systems, clean with jet-vacuum as needed to remove sediment build-up

E. Clear Stormwater Flow Paths

- Stiff broom inlet structures and at least twenty feet of curb/gutter upstream of inlet structures

(Photo placeholder)

F. Repair Erosion & Material Settlement

- Inspect engineered channels and outfalls for erosion gullies or signs of subgrade displacement
- Replace and stabilize surface material as needed to bring to original grade
- Report excessive erosion causing structural failures (i.e., near inlet, outlet, or weir structures, etc.)
- Notify the appropriate authority if erosion continues to occur in the same area

(Photo placeholder)

5609.6 Retention & Detention Practice Maintenance Tasks

A. Inspect for Standing Water

During every site visit, inspect for standing water and mosquito larvae
Inspect site 48-hours after a large rainfall event of 3-inches or more in a 24-hour period

B. Inspect Structural Conditions

Report to the appropriate authority any observation of:

- Damaged or broken concrete curbing
- Uneven or sinking pavement or curbing
- Loose or damaged bollards or fencing
- Loose or damaged inlet structures, outlet structures and/or grates
- Damaged or sinking weirs

C. Trash & Debris Removal

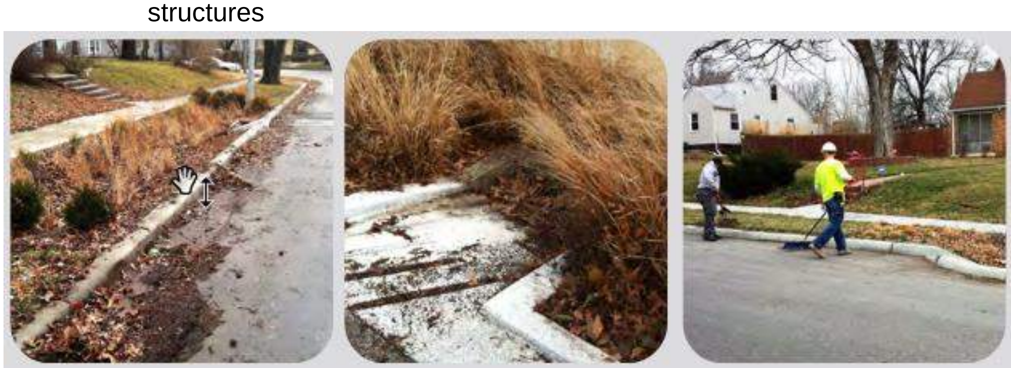
- Trash and debris may impede flow of stormwater to inlets or outlets
- Remove by hand or with lightweight equipment (litter pickers)
- Larger buildups may need removed with special equipment
- Report observations of large dumped items such as furniture, tires, bags of trash, etc. to the appropriate authority.

D. Sediment Removal

- Sediment may impede flow of stormwater to inlets or outlets
- Use a shovel to remove sediment buildup or blockages
- Replace any surface materials that were removed during sediment removal
- Clean or replace filter bag/basket in inlet, outlet, and pretreatment Structures

E. Clear Stormwater Flow Paths

- Stiff broom inlet structures and at least twenty feet of curb/gutter upstream of inlet structures



F. Repair Erosion & Material Settlement

- Inspect GSI for erosion gullies or signs of soil, aggregate, or mulch displacement
- Replace and stabilize surface material as needed to bring to original grade

- Report excessive erosion causing structural failures (i.e., near inlet, outlet, or weir structures, etc.)
- Notify the appropriate authority if erosion continues to occur in the same area

G. Vegetative Maintenance

Because vegetative stormwater management practices are living, functional assets, the overall success of vegetated stormwater practices is contingent on proper establishment of the landscape plantings. Unlike traditional collection and conveyance structural stormwater infrastructure, vegetative practices are weakest immediately after install. Where traditional infrastructure weakens over time, vegetative practices grow stronger and more functional the more established they become. For this reason, vegetative maintenance tasks are discussed in this section in terms of the following time periods:

- Plant Establishment Activities
- Monitoring Activities
- Maintenance Activities

Dense vegetation is required to support infiltration functions, provide an attractive infrastructure amenity, and reduce long-term management demands. Managing and maintaining these practices requires a different approach than the traditional landscape practices of mowing, weed-eating, and mulching. Landscape designs shall consider long-term maintenance responsibility and capacity. The main management goals should include keeping the landscape attractive, legible, and functional. Other goals may be specific to the type of practice and/or context of the site.

GSI Landscape Management Approach

For the layered planting design approach outlined in GSI-7 Landscaping (Section 5606), management decisions should not try to keep the plantings in static state but allow plants to move around, fill in gaps, and function as a plant community to reduce the need to replace dead plants. This planting design and management approach can work to reduce plant replacement costs, installation labor, and soil disturbance.

Landscape management guidance is provided for both the establishment and maintenance phases. The activities required to achieve successful plant establishment, and the regular monitoring and maintenance activities required for the life span of the GSI facility. Photos are included to show various GSI features and describe the tasks that should be completed for each.

Manage the Layers

- Structural: These plants form the bones of the layered design and are critical to the legibility of the design. Management practices should strive to preserve this layer as it was designed. If structural plants are lost due to disturbance, disease, or other natural causes they should be replaced in kind or with another species with similar characteristics.

- Seasonal: These plants provide the main floral display and are important to the visual appearance of the design. Management practices should ensure these plants remain in quantities specified as part of the design, but it is acceptable if these plants move around by re-seeding or through vegetative means (rhizomes). Some editing (removal) of the seasonal plants may be necessary if any spread aggressively.
- Groundcover: These plants are the workhorses of the planting bed by covering the ground, helping to outcompete weeds, and acting as living layer of 'green mulch'. The groundcover plants are expected spread and fill in and around the structural and seasonal plants. Management practices should ensure the groundcover plants are filling gaps and at minimum are in the quantities specified in the landscape plans.

Plant Establishment Activities:

Watering

Native plants do not need continuous watering. Excess watering can favor weed growth. During the first growing season (Year 1 of establishment), new plantings should be watered every other day for the first two weeks after planting. For the following weeks, water newly installed plants weekly until the first freeze of the planting season occurs.

Following the first year, watering should only occur in periods of extreme drought and to help establish replacement plants. Any replacement plants need to be watered every other day for the first two weeks after planting. For the following weeks, they should be watered on a weekly basis until the first freeze of the planting season occurs.

During Years 2 and 3 of establishment, if less than ½-inch of rain falls for two consecutive weeks anytime between April 1st to November 30th, water planting beds to completely saturate soil to a depth of 4 inches and continue every two weeks until rainfall resumes.

Dewatering

For the first growing season, lower the elevation or open the outlet control structure to allow water to flow through the GSI facility rather than pond, allowing conditions for the vegetation to establish. As vegetation matures, the facility will handle increased stormwater ponding.

Weeding

Weeds are defined as plants that were not installed as part of the project. If plants are found that were not originally installed but are identified as beneficial plants, consult the Owner for directions prior to removal. Identify weed species to determine the appropriate Integrated Vegetative Management techniques. Cut back and remove all annual and biennial weed species, unless alternative methods have been previously approved. Hand pulling of weeds is not recommended as it creates soil disturbance and provides opportunity for weed seeds to germinate. For perennial weed species use the mildest effective measures to remove the weed and prevent its return.

- Maintain GSI Components so they are free of weeds at ALL times
- Refer to original planting plans to understand what plants should remain
- Identify type of weed species to determine the appropriate method of removal
- Apply pre-emergent herbicide granules per manufacturer's recommendations. Document application with photographs and provide date completed

- Consult the appropriate authority prior to removing volunteer beneficial plants not originally installed

- If chemical methods for weed control are needed, only use methods approved by the appropriate authority and listed in the GSI Inspection and Maintenance Field Guide
- Blue marker dye is recommended in all liquid chemicals before use
- Do not apply chemicals within 24-hours of a forecasted rain event and use according to the product label
- Any person applying chemicals for weed management must be a State (Missouri or Kansas) Certified Applicator

Mulching

Mulch is beneficial during establishment to conserve soil moisture and help prevent weed seeds from germinating.

- Rake displaced mulch to even and consistent depth.
- Remove mulch from tops and sides of inlets, outlets, or pretreatment structures
- Refresh double ground hardwood mulch as needed cover any bare soil areas to maintain a 3-inch depth.
- Mulch can be added year-round (but recommended at end of Spring).
- Ensure mulch is pulled away and not covering the crown of the plants or mounded against tree trunks.
- DO NOT place mulch within 2-inches of plants and 4-inches of tree trunks.

Monitoring Activities

Inspect Health & Appearance of Vegetation

Inspect GSI landscape for overall health and appearance of vegetation. Vegetation should have a tidy appearance with clean, distinct planting edges. Knowing when the various plants emerge in the Spring is important to evaluating and maintaining the GSI landscape. For example, the native sedges or cool season plants should start showing signs of growth in late winter to early spring. Warm season grasses and perennials wait until late spring to early summer to push out new growth. For example, Butterfly Milkweed is a warm season perennial that will be one of the last to show new growth in the spring.

- Inspect for signs of excessive drought, disease, nutrient deficiency, and/or pest problems
- Identify observed weeds or bare spots requiring mulch or vegetation replacement.

Maintenance Activities

Landscape Edges

Landscape edging (metal landscape edge, concrete edge, cultivated edge, etc.) should be clean, distinct, and visible. If plants are covering edges, streets, or surrounding pavement, properly prune or reposition the plants to uncover those surfaces. If edging material has sunken, raise it up to original grade.

Prune Plants

Prune plantings as needed in a manner appropriate to species type and to encourage compact growth habit. Maintain vegetation so that it is confined to intentionally planted areas. Conduct cosmetic pruning as needed for dead or broken stems and branches. NEVER use a string-line trimmer or mower to prune plants. If plants are covering landscape edges, streets, or surrounding pavement use hand pruning shears to properly prune plants

- Perennials and Grasses:
  - In late February to early March, cut back previous season's foliage to 3"-6" above the plant crown and remove all cuttings from site
  - Depending on species, some plants may need dividing or thinning every 3-5 years to prevent overcrowding and encourage air circulation between individual plants
  - Prune (pinch back) the mid to late summer blooming perennials to ensure a more compact and tidy form if desired.

- Shrubs:
  - Remove only damaged, dying or dead branches
  - Prune to maintain natural character/form, do not prune into balled or boxed forms except for where specifically instructed
- Trees:
  - Tree pruning must be performed by a certified arborist

Mowing (Perimeter)

Mow or neatly string-line trim to a height of 2 inches, a 3-foot buffer around GSI perimeters and lawn areas contained within the GSI. Broom or blow resulting grass clippings into the mowed grass area(s). Do not leave clippings on paved, gravel, or mulched surfaces. Do NOT mow non-lawn vegetation within the GSI footprint. Immediately contact Owner and request written clarification if mowing extents are unclear.

Mowing (Turf grass areas)

Mow turf grass areas as needed. If turf grass is within the GSI infiltrating surface, mow or neatly string trim to height of 3 to 5 inches. DO NOT mow non-lawn vegetation within the GSI footprint. If mowing extents are unclear, request written verification from the appropriate authority.

- Use a string-line trimmer to manage turf along landscape edges, streets, or surrounding pavement
- Mow turf grass lawn areas to a height of 3 to 5 inches
- Broom or blow resulting grass clippings into the mowed grass area. DO NOT leave clippings on paved, gravel, or mulched surfaces

Remove Dead Plants & Install New Plants

Contact Owner before installing replacement plants and replace dead plants as directed by the Owner. Replacement plants should be planted either in Spring or Fall to minimize heat stress to plants.

- Photograph and record locations for trees, shrubs and plants that are more than 75% dead and submit a Work Order to the appropriate authority for plant removal and replacement.
- Replacement Planting Process:
  - Install nursery grown perennials & grasses in Spring (April 15 – May 31) or Fall (September 15 – October 15).A .
  - Install nursery grown trees & shrubs in Spring (March 15-May 31) or Fall (September 15 to December 15). For early Spring or late Fall plantings, avoid planting if the ground is frozen.
  - Dig planting pit two times wider than the root ball.
  - Add soil amendments to the planting pit as necessary.
  - Backfill around root ball in layers, tamping soil to eliminate voids and air pockets.
  - Water newly installed plants to completely saturate soil to a 4-inch depth weekly until the first freeze of the planting season occurs.

Disease and Pests

Follow Integrated Pest Management principles to manage diseases and pests that could threaten plant or human health as well as to manage weeds. Review Integrated Pest Management information available from the University of Missouri Extension and Kansas State University Research & Extension.

- Report any observation of animal burrows larger than 1-inch to the appropriate authority
- Identify pests and disease species to determine appropriate method of removal
- All chemical controls must be applied by a State Certified Applicator
- Install mosquito dunks per manufacturer's recommendations in location of observed mosquito larvae

Algae and Aquatic Weeds

Identify the type of algae or aquatic weed present. The materials employed will be registered for aquatic usage with the Environmental Protection Agency and States of Kansas or Missouri. Treatments should be applied in compliance with product/manufacturer guidelines.

5609.7 Natural Area Management

A. Natural Areas

Natural areas with native vegetation used in stormwater management do require maintenance, but not as frequently as traditional, exotic landscaping. Natural community responses to restoration treatments, however, can be dynamic and unpredictable. For this reason, native landscape management and maintenance strategies need to be flexible and allowed to change over time to respond to natural communities as they adjust to restoration intervention treatments. Careful monitoring and evaluation of community responses are critical steps in an adaptive management process. This allows for measured changes in the timing and application of specific treatments to better improve the overall performance of the site. For these reasons, a vegetation management plan should be developed that allows adaptive management, not absolute prescriptive management. The plan is a starting point in an ongoing process that relies on monitoring to provide feedback on program effectiveness and for evaluation of the need and justification for changes in the management plan. This process of evaluation, adjustment, refinement and change is adaptive management, and it is fundamental to the effective restoration and management of natural communities. Adaptable management and maintenance plans are fundamental to the health, longevity, and ultimate success of the restored native landscapes. Maintenance tasks may include periodic use of chemical and mechanical removal of invasive species, and modest enhancement seeding and planting. While this phase of the program can be viewed as a routine maintenance program conducted annually at strategic times to achieve and maintain specific ecological and biological objectives, management decisions must remain responsive to the guiding principle of adaptive management. General, on-going tasks include inspection of both preserved and restored natural areas periodically to monitor plant survival. Natural areas need to be protected from excessive pedestrian traffic, pest infestations, and other potential damage caused by storm events, wildlife and humans. Specialized training for restoration and management tasks of any vegetation is often necessary. For many of the restoration tasks (i.e. prescribed burning, herbicide use, and monitoring) specialized training, often licensing or certification, and oversight and guidance are required well in advance of the dates for commencement of the restoration program. Personnel and volunteers involved in prescribed burning, brush control, monitoring, seed collection, etc., should receive training commensurate with the activity in which they would be involved. Training is especially important for those activities that may have risk and safety implications (i.e. prescribed burning), but also for monitoring, where an accurate assessment of the ecological performance of the ecological system to the restoration treatments is required.

B. Upland Areas

Conserving existing upland native vegetation demands less maintenance than turf grass plantings or other landscaping, reducing operations and maintenance costs. Minimal mowing and herbicide application is needed to maintain a healthy stand of native vegetation. Some mechanical means may be necessary to control invasive species and preserve the health of the system. Minimal to no fertilization is required. Establishing native uplands necessitates that seeded areas be kept moist during the first weeks of establishment; mulch is also recommended. Reseeding may be necessary when the first seeding does not produce a vigorous stand. Mowing is only occasionally necessary, and fertilizers are not required to maintain a healthy stand of native vegetation. If controlled burning is not an option, mowing can control unwanted deciduous growth that may encroach on prairie plantings

C. Bottomlands and Floodplains

Once established, native vegetation in floodplains requires little maintenance. Depending on the desired use of the floodplain, general maintenance may require replacement of dead or undesirable trees and shrubs to prevent overpopulation of undesirable species; selectively harvesting trees and shrubs to reduce overgrowth, and control of invasive species. Mechanical means or prescribed burning may be necessary to manage the area. For wetlands, ponds or frequently inundated areas, inspect the areas periodically to monitor plant survival. Protect it from excessive sedimentation; pest infestations; and other potential damage caused by storm events, wildlife, and humans. Replace dead trees, shrubs, and herbaceous vegetation. Periodically control undesirable vegetative competition. Remove excessive buildup of sediment, storm debris, and trash.

D. Stream Buffers

Once established, native vegetation in stream buffers requires little maintenance. General maintenance may require replacement of dead or undesirable trees and shrubs to prevent overpopulation of undesirable species; selectively harvesting trees and shrubs to reduce overgrowth, and control of invasive species. Mechanical means or prescribed burning may be necessary to manage the area. For frequently inundated areas, inspect the stream buffer periodically to monitor plant survival. Protect it from excessive sedimentation, pest infestations, and other potential damage caused by storm events, wildlife, and humans. Replace dead trees, shrubs, and herbaceous vegetation. Periodically control undesirable vegetative competition. Remove excessive buildup of sediment, storm debris, and trash.

5610

SUBMITTAL REQUIREMENTS

NOTE: FORMATTING IS NOT COMPLETED ON THIS SECTION

5610 Submittal Requirements

This section defines the stormwater management submittal requirements for planning, design and construction of the stormwater improvement components of a project. The following submittals are described in this section:

1. Stormwater Concept Analysis
2. Stormwater Drainage Report
3. Design & Construction Plans
4. Construction Specifications

5610.1 Stormwater Concept Analysis

The **Stormwater Concept Analysis** is an exercise to consider stormwater management during early stages of the project. The purpose is to identify existing and potential drainage issues and delineate required stormwater infrastructure early in the development process so that stormwater management is proactively planned for with improvements. This also prioritizes evaluating the preservation, restoration, and runoff reduction opportunities to address the stormwater volume, quality, and peak flow rate impacts caused by changes to the land surface. The Stormwater Concept Analysis shall include the following items and associated project details:

A. KC Compliance Calculator Tables

The following tables should be provided for all applicable stormwater drainage system components. These tables can be found in the **KC Compliance Calculator,** with printouts of forms shown in **Appendix D**.

1. **General Requirements**: designer shall input project information to determine what stormwater management requirements apply, if any. Inputs include the following information for project information, site parameters, and stormwater management requirements and/or variance requests as defined in **Section 5602**:

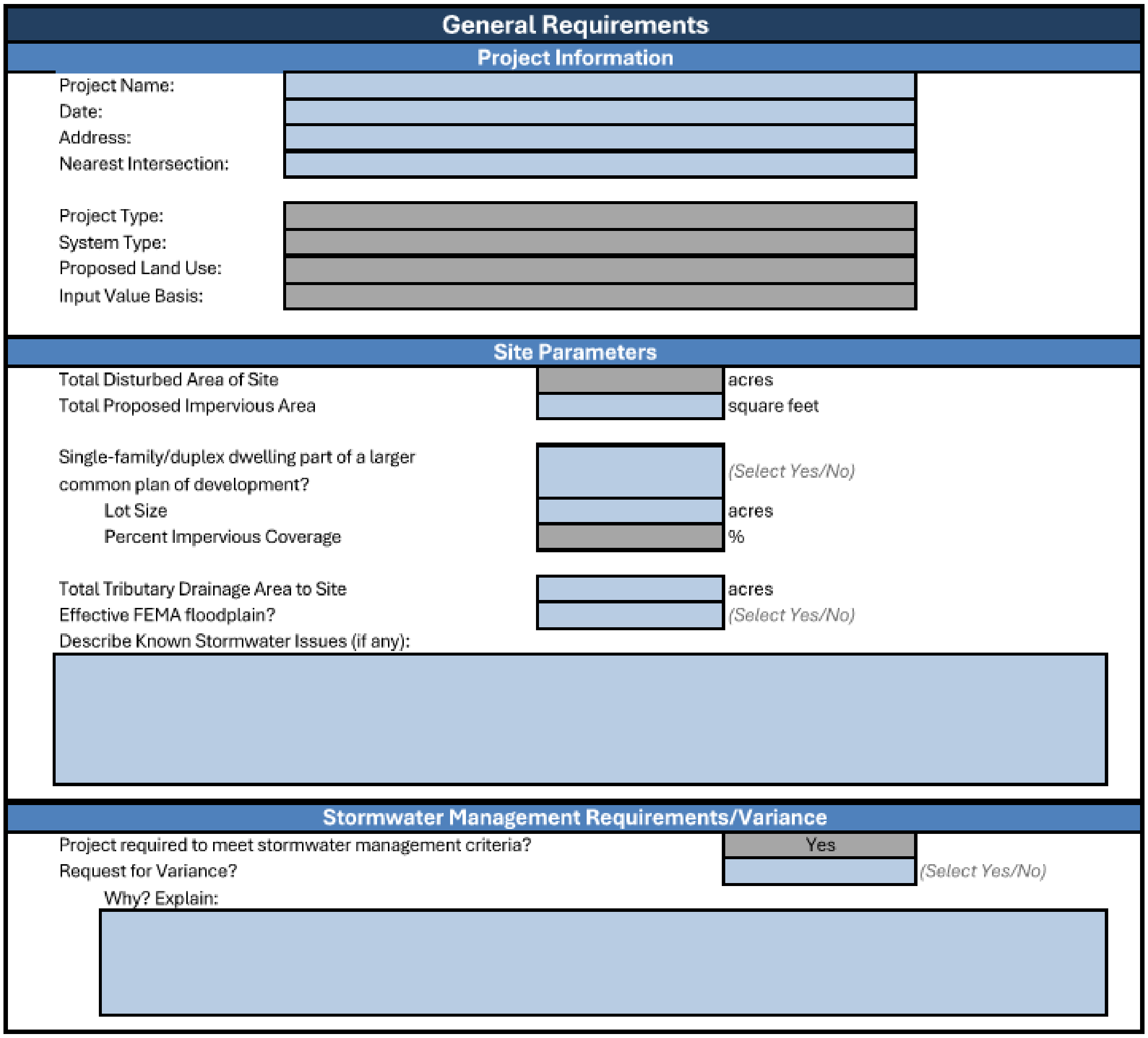


Figure 5610-1: KC Compliance Calculator General Requirements

2. **Designer Verification of Compliance with Design Criteria**: designer shall verify that the referenced sections of this design criteria have been met, or are not applicable. Inputs include the following information for preservation, restoration, retention, detention, collection, and conveyance requirement verification:

Landscape Professional Verification of Compliance with Design Criteria	
Preservation/Restoration	
Requirements Met?	**Design Criteria**
☐ Yes ☐ No ☐ N/A	Stream setbacks meet requirements of Section 5604 and placed within a separate dedicated tract of land restricted from future development?
☐ Yes ☐ No	Project incorporates preservation or restoration of Natural Areas?
☐ Yes ☐ No ☐ N/A	Natural Area meets requirements of Section 5604?
☐ Yes ☐ No ☐ N/A	Natural Area placed within a separate dedicated tract of land restricted from future development?
☐ Yes ☐ No ☐ N/A	Project incorporates the following Sustainable Stormwater Management Practices and RRV reductions meeting requirements of Section 5602 and 5604 (select all that apply):
☐ Yes ☐ No ☐ N/A	Sheetflow to Natural Areas
☐ Yes ☐ No ☐ N/A	Sheetflow to Natural Areas
☐ Yes ☐ No ☐ N/A	Downspout Disconnection (not applicable for residential developments)
☐ Yes ☐ No ☐ N/A	Preservation of Existing Trees or Planting New Trees?
	Total RRV Reductions: 0 (cf)
	I hereby certify, as a Landscape Professional, that the information in the Preservation/Restoration section of this form was assembled under my direct personal charge and is in compliance with the Stormwater Management Criteria.

Professional Name	License Number	State

Figure 5610-2: KC Compliance Calculator Designer Verification – Preservation & Restoration

Professional Engineer Verification of Compliance with Design Criteria			
Retention			
Requirements Met?	**Design Criteria**	**Retention Volume (cf)**	
☐ Yes ☐ No ☐ N/A	Required Retention Volume met per Section 5602?		
☐ Yes ☐ No ☐ N/A	Easement(s) provided?	***Required***	***Designed***
	RRV (prior to RRV Reductions)	0	0
	RRV (with RRV Reductions)	0	
Detention			
Requirements Met?	**Design Criteria**	**Release Rates (cfs)**	
☐ Yes ☐ No ☐ N/A	Easement(s) provided?	***Maximum Allowable***	***Designed***
☐ Yes ☐ No ☐ N/A	2-year peak outflow control achieved?		
☐ Yes ☐ No ☐ N/A	10-year peak outflow control achieved?		
☐ Yes ☐ No ☐ N/A	100-year peak outflow control achieved?		
Collection			
Requirements Met?	**Design Criteria**		
☐ Yes ☐ No ☐ N/A	Inlet placement and gutter spread per requirements of Section 5607?		
Conveyance			
Requirements Met?	**Design Criteria**		
☐ Yes ☐ No ☐ N/A	Easement(s) provided?		
☐ Yes ☐ No ☐ N/A	Enclosed pipe systems per requirements of 5608.2?		
☐ Yes ☐ No ☐ N/A	Minor drainage systems per requirements of 5608.3 A?		
☐ Yes ☐ No ☐ N/A	Designated overflow routes for 100-year design storm per requirements of Section 5608.3 B?		
☐ Yes ☐ No ☐ N/A	Channel stabilization per requirements of 5608.4?		
☐ Yes ☐ No ☐ N/A	Road crossings per requirements of 5608.5?		
	I hereby certify, as a Professional Engineer, that the information in the Retention, Detention, Collection, and Conveyance sections of this form were assembled under my direct personal charge and is in compliance with the Stormwater Management Criteria.		
	Professional Name	License Number	State

Figure 5610-3: KC Compliance Calculator Designer Verification – Retention, Detention, Collection, & Conveyance

3. Calculation Tables: include the following calculation tables for applicable stormwater drainage system components to serve as documentation that design criteria requirements have been met.

- Site Inputs/Drainage Areas
- Retention (for each drainage area)
- Detention (for each drainage area)

4. **Maintenance Requirements & Responsibilities**: Input entity(ies) responsible for the maintenance during each project time period to the best available information. This form shall be updated with subsequent plan submittals. A maintenance manual is required to be submitted and recorded with the deed or plat for the property, meeting the requirements of **Section 5609**.

Maintenance Requirements & Responsibility

Storm Drainage System Components

Select all applicable components of the storm drainage system design

- Preserved Natural Areas ☐
- Restored Natural Areas ☐
- Retention & Detention Practices ☐
- Collection Practices ☐
- Conveyance Practices ☐

During Construction

Anticipated Construction Start	Month	Year
Anticipated Construction Completion	Month	Year

Responsible Party

Name	Address	Phone

Warranty and/or Vegetation Establishment Period

Anticipated Vegetation Install Start	(month)	(year)
Anticipated Vegetation Install Completion	(month)	(year)

Responsible Party

Name	Address	Phone

Long-Term Owner (Post-Warranty Period)

Describe source of funding and the mechansim for maintenance of stormwater drainage system:

Responsible Party

Name	Address	Phone

Certification

I hereby certify as the Owner of this property that the maintenance responsibility information specified herein is accurate, and that responsible parties are aware of the maintenance activities required for all components of the stormwater drainage system.

Figure 5610-4: KC Compliance Calculator Maintenance Requirements & Responsibility

B. Watershed Location Map

Designer shall develop a **Watershed Location Map** to identify the project's location within the greater watershed, which shall depict the following:

1. Watershed boundary and area (acres)
2. Delineated drainage area tributary to the project site (acres)
3. Natural overland drainage paths to, through and downstream of the project site to the downstream destination of runoff (whether open channel or enclosed system)
4. Water bodies and regulatory floodplain
5. Existing stormwater retention/detention facility location(s) in upstream or downstream watershed affecting stormwater management at project site (if applicable)

C. Existing & Proposed Site Conditions Maps

Designer shall develop two **Site Conditions Maps**, one for existing conditions and one for proposed, to compare existing site drainage with proposed site drainage. This map is used to verify that proposed site conditions mimic natural topography, maintain required stream setbacks, and apply stormwater management practices appropriately. The following shall be depicted on the Site Conditions Maps:

Existing Site Conditions

1. Contours
2. Aerial imagery, most current
3. Water bodies and regulatory floodplain
4. Natural overland drainage paths and discharge points from the site
5. Utilities, including existing stormwater infrastructure
6. Parcel boundaries
7. Impervious surfaces and types (i.e. building, parking lots, gravel, etc.)

Proposed Site Conditions

1. Contours including finished floor elevation (FFE) and lowest opening elevation (LOE)
2. Utilities, including existing stormwater infrastructure
3. Designated overflow routes and discharge points from the site
4. Drainage areas labeled with IDs and acreages correlating to the KC Compliance Calculator inputs, including **uncontrolled drainage area**
5. Parcel boundaries, required utility easements, stream setbacks identifying key features and statistics (**top of bank** or **bank-full** extents, centerline, Zone 1, and Zone 2, and dimensional offset), and **Natural Areas** with key statistics (total footprint, minimum length and width).
6. Impervious surfaces and types (i.e. building, parking lots, gravel, etc.)
7. Stormwater improvements including:
   a. Natural Areas of preservation and/or restoration
   b. Preserved Trees
   c. New Trees
   d. Retention Practices
   e. Detention Practices
   f. Collection Practices
   g. Conveyance Practices

5610.2 Stormwater Drainage Report

If variances or exemptions to the stormwater management requirements are requested for a project, a **Stormwater Drainage Report** is required. For projects not pursuing any variances or exemptions to the stormwater management requirements, the Stormwater Concept Analysis is sufficient and no Stormwater Drainage Report is required. The Stormwater Drainage Report shall be sealed by a Professional Engineer registered in the state of the project.

The Stormwater Drainage Report shall include all of the Stormwater Concept Analysis Submittals with the additional narrative sections:

A. Project Narrative

The project narrative should elaborate on the site input parameters in the general requirements table provided with the Stormwater Concept Analysis including the following:

- Purpose of the project: description of why the project is being designed/constructed

- Site description: description of the existing site use(s)
- Design requirements: identify the applicable design criteria as defined in **Section 5602**
- Variance requests: identify the applicable exceptions/variances being pursued for the project

B. Existing Conditions

The existing conditions section should provide a narrative description expanding on the information shown in the watershed location map and existing conditions map provided with the Stormwater Concept Analysis, including the following:

- Watershed Location: description of the watershed in which the project is located including topography, land use/soil types, infiltration testing results, obstructions within downstream overland drainage paths, and receiving water bodies.
- Existing Storm System: designer should identify whether the public sewer system receiving flow from the site is a Combined Sewer System (CSS) or a Municipal/Transportation Separate Sewer System (MS4 or TS4); or if the site discharges directly to a receiving water body.
- Existing System Capacity: the designer should calculate the capacity of the existing conveyance system (whether CSS, MS4 or TS4, or an open channel) downstream of the project site and provide a table describing pipe or channel size/shape, material, slope, and pipe full (or channel full capacity).
- Identify any previously known/documented or calculated downstream drainage issues.
- Stream assessment: if improvements are proposed within required stream setbacks a stream assessment per **Section 5610.5** is required.

C. Proposed Conditions

The proposed conditions should include a discussion of the proposed stormwater management practices for the site, the evaluation completed to meet the design criteria, and justification for proposed variance/exemption from any requirement and documentation of the analysis and efforts to meet requirements completed to date. Include calculation tables and narrative descriptions of assumptions and inputs. The proposed condition should include subsections for each of the following:

1. **Preservation & Restoration Practices**
2. **Retention Practices**
3. **Detention Practices**
4. **Collection Practices**
5. **Conveyance Practices**

D. Operations and Maintenance

The operations and maintenance section should describe the types of maintenance tasks and recommended frequencies that each task should be performed for each stormwater system component. This information helps the Owner determine the level of effort and equipment needed to maintain the proposed condition of the site and to coordinate appropriate reviews by staff, as needed.

E. Stakeholder & Public Engagement

If applicable, designer should include a narrative summary of all stakeholder and public engagement completed for the project to date. Providing multi-benefit infrastructure that enhances value to the property or public is one of the primary goals of integrating green stormwater infrastructure (GSI) into projects. The report should document the targeted stakeholder audiences, the engagement activities completed to date and reactions from the public, and planned engagement through the remaining life of the project.

F. Appendices

Additional project information that is relevant to the stormwater drainage analysis shall be included in an Appendix to the report. This information may include but not be limited to:

- Modeling Results: results from computer software used shall be included as an appendix to the report. If requested, designer shall provide a digital copy of input and output data files
- Related studies (i.e. regional stormwater management analyses, wetland determinations, stream bank stability studies, etc.)
- Determinations from other regulatory agencies
- Geotechnical investigations
- Infiltration testing results

5610.3 Drawing Requirements

The Construction Drawings shall include all information necessary to build and verify the design of the **storm drainage system** and related appurtenances. Drawings shall be accompanied by finalized versions of the **KC Compliance Calculator** tables submitted with the **Stormwater Concept Analysis**.

The Construction Drawings shall be sealed by a Professional Engineer and/or a Registered Landscape Architect in the state where the project is located, as applicable per the stormwater management systems and/or facilities designed. Drawings shall be submitted for review to the **approving jurisdiction**. The following subsections are intended to provide minimum information and level of detail that the designer should verify is included in the construction documents. The drawings shall be arranged as required by the approving jurisdiction, which may include requirements in addition to those specified herein.

A. Sheet List

The following shall be included in the Construction Drawings for stormwater infrastructure, at a minimum. Reference **Section 5610.3 B.** Drawing Best Practices for additional recommended guidance for plan sheet standards.

General Layout

General layout sheet(s) shall include the overall storm drainage system (existing and proposed), labeling all stormwater preservation, restoration, retention, detention, collection, and conveyance components with IDs correlating to the Stormwater Concept Analysis calculations. Include floodplain and stream setback extents, as applicable.

Temporary Erosion & Sediment Control/Stormwater Runoff Management Plans

Temporary erosion and sediment control plan(s) shall include Stormwater Runoff Management Plan requirements for control and protection of preservation, restoration, retention, detention, collection and conveyance practices within the project's disturbed area. Notes shall be included indicating that the erosion control measures shall be monitored and maintained throughout the project life, adjusted as necessary to control erosion, and be removed upon project completion once authorized to do so by the approving jurisdiction. Designer shall include any phasing specific notes and direction necessary to maintain protection throughout the duration of construction.

Site Plan

Site plan(s) shall indicate property lines, easements, dedicated tracts and required stream setbacks (as applicable).

Drainage Area Map

Drainage area map(s) shall depict boundaries and drainage area IDs correlating to the Stormwater Concept Analysis calculations. Drainage area map shall show overland flow path(s) tributary to the site as well as downstream of the site. Identify designated overflow route(s) for stormwater flows greater than the designed conveyance system capacity through the site and **discharge points** from the site.

Grading Plan

Grading plan(s) shall identify all stormwater management practices and **Survey Verification Points** and spot elevations within the finished grade of all stormwater management practices for contractor verification during construction. Grading plans shall include existing and proposed contours at a minimum 1-foot intervals, and elevation information such as buildings, curbs, walls, and other information pertinent to the site.

Landscaping & Restoration Plans

Landscaping and restoration plans shall define restoration for the entire disturbed area of the project. Planting plans shall meet requirements of **Section 5606**, GSI-7.10 Planting Plan

Plan & Profile

Plan and profile sheets shall show the pipe/channel alignments in plan view and the corresponding profile within the same sheet, when possible. Length, size, and slope of each segment shall be shown along with hydraulic grade line of the underground components. Structure labels shall identify type and size of structure to be installed, RIM, and invert elevations. All utility crossings shall be shown in plan and profile, located and identified as to the type, size and material to the best information available and provided through records, field prospecting and/or utility potholing/excavation.

Stormwater Cross Sections & Details

Plans shall include cross-sections and details for all open channel and/or **GSI Practice**s specified on the project. Traditional stormwater infrastructure details shall also be included, such as curb and gutter, inlets, manholes/junction boxes, pipe bedding and backfill. This manual provides guidelines and tools that are generalized for the MARC region. It is the designer's responsibility to coordinate with the approving jurisdiction to include all jurisdiction-specific standard details and requirements.

GSI Component details shall be included, as summarized in **Section 5610.3 C**.

Include structural details showing dimensions, reinforcing, base and subgrade preparation requirements, as applicable.

B. Drawing Best Practices

Plan Sheets

In addition to the sheet specific required information described in **Section 5610.3 A**. Sheet List, designer should consider including the following information on all plan sheets, as applicable and legible:

- Surveyed or aerial base map indicating benchmarks, test borings, existing man-made or natural topographic features, such as buildings, fences, trees, channels, ponds, streams, existing and proposed utilities, etc.
- Parcel information including but not limited to rights-of-way, property and parcel lines, existing and proposed easements, subdivision nomenclature, and other pertinent information impacting or impacted by the project. Label addresses of properties abutting the projects and current property owner names associated with properties impacted by the project
- Street names
- Identification and location of all existing storm drain system features including ID, type, material, size, and elevations. Jurisdiction-specific asset IDs should be used, when available.
- Proposed storm drain system features. Structure IDs should be shown on all sheets for ease of orientation and correlation to other relevant plan sheets. Pertinent structure information should only be shown on the relevant sheet (i.e. northing/eastings, RIM and invert elevations, etc.), with ID only shown for reference on other sheets.
- Existing and finished grade contours at intervals of 2 feet or less in elevations; or equivalent detail indicating existing and finished grade and slopes
- Uniform set of symbols consistent with requirements of approving jurisdiction
- Notes to contractor conveying pertinent detail for construction to meet the design intent, as necessary. Coded notes are recommended for repetitive callouts or notes that are necessary for numerous sheets.

North Arrow

North arrow shall be included on all plan sheets. When practical, north arrow should be oriented up or to the right.

Sheet Sizes

The suggested sheet size is 22” X 34” with 2-inch binding margins along the left end of sheets such that plans can be printed at half-size on 11” X 17” paper. All sheets in a given set of plans shall be of the same size.

Scales

Scales shall be shown on each sheet and all details. Plans shall be drawn to a scale such that all relevant text and features are legible Table 5610-1 shows recommended minimum scales, though other scales may be needed to clearly present the design.

Table 5610-1: Recommended Plan Scales

Drawing Type	Scale (inches : feet)
Plan Views	1: 20
Profile Views	
Horizontal	1:20 (or matching plan view scale)
Vertical	1:5
Cross Sections	
Horizontal	1:10
Vertical	1:5
Drainage Area Map	
Onsite	1:200
Offsite	1:1,000
Structural Plans	¼:1

C. Retention & Detention Design Components Plan Requirements

Projects that incorporate retention and/or detention practices shall include sufficient level of detail for construction of the practice itself as well as its design components. Designer shall verify that the design has evaluated and includes the minimum required and recommended components, as applicable. Table 5610-2 summarizes the minimum applicable design components for each GSI Practice, discussed in further detail in **Sections 5605 and 5606**. The subsequent sections summarize the minimum plan requirements applicable to each GSI Component.

Table 5610-2: GSI Design Components for Retention & Detention Practices

	GSI Component										
	GSI-1	GSI-2	GSI-3	GSI-4	GSI-5	GSI-6	GSI-7	GSI-8	GSI-9	GSI-10	GSI-11
Bioretention	●	●	●		●	●	●	●	●	●	●
Rain Garden	●	●	●		●		●		●		●
Permeable Pavement System			●	●	●	●		●	●	●	●
Infiltration Trench	●	●	●		●	●		●	●		●
Extended Detention Wetland	●	●	●		●	●	●	●	●		●
Extended Wet Detention Basin	●	●	●		●	●	●	●	●		●
Extended Dry Detention Basin	●	●	●		●	●	●	●	●		●
Subsurface Storage	●	●			●	●		●	●	●	●
Green Roof			●		●	●	●		●		●
Blue Roof			●		●	●	●		●		●
Cistern	●	●						●	●	●	●
Pretreatment*	●	●	●		●	●	●	●	●		●

*Pretreatment includes Native Vegetation Swale, Vegetated Filter Strip, Sand Filter, Proprietary Media Filtration, Hydrodynamic Separator, Baffle Box/Grit Separator, Oil-Water Separator, and Catch Basin Insert, which may include one or more of the GSI Components indicated in the table above.

GSI-1 Inlets

- Plan view of GSI Practice indicating location of inlet structure(s) including northing/easting points.
- Spot elevations to show drainage path towards the inlet structure(s) as well as the **designated overflow route** and bypass for storm events that exceed the design capacity of the GSI Practice.

- Detail/Section view of inlet structure(s) specifying recommended product/manufacturer, size, dimensions, and elevations (as applicable).
- Detail of anchoring design to prevent flotation (as applicable).
- Inlet capacity calculations (if required to include on the design plans by the approving jurisdiction).

GSI-2 Energy Dissipation & Pretreatment

- Plan view of GSI Practice indicating location of energy dissipation/pretreatment device including northing/easting points for extents of component (as applicable).
- Detail/Section view of energy dissipation including aggregate and/or surface stone/brick size, depth, extents, and elevations (as applicable).
- Detail/Section view of pretreatment device including recommended product/manufacturer, size, dimensions, and elevations (as applicable).
- GSI designed maximum entrance velocity, permissible shear stress, and aggregate and/or stone size calculations (if required to include on the design plans by the approving jurisdiction).

GSI-3 Area Protection

- Plan view of GSI Practice indicating location of area protection component(s) including northing/easting points and elevations.
- Detail/Section view of area protection component(s) specifying recommended product/manufacturer, size, and dimensions (as applicable).

GSI-4 Permeable Pavements

- Specify in-situ infiltration testing locations and frequency for all GSI Practies. Reference Specification Section 02956 Green Stormwater Infrastructure In-situ Infiltration Testing for recommended test methodology.
- Plan view of GSI Practice specifying extents of permeable pavement with northing/easting points, and elevations.
- Detail/Section view of GSI Practice specifying type of permeable pavement, with type and depth of aggregate media layers, referencing material specifications.
- Grading plan shall identify Survey Verification Points along the boundaries of the permeable pavement and spot elevations within the finished grade of the pavement for contractor verification during construction.

GSI-5 Soil & Aggregate Media

- Specify in-situ infiltration testing locations and frequency for all GSI Pites. Reference Specification Section 02956 Green Stormwater Infrastructure In-situ Infiltration Testing for recommended test methodology.
- Storage capacity calculations including tributary drainage area, impervious tributary area, required retention volume (RRV), soil and aggregate component storage volume, and storage volume provided by retention practices (VR), including any ponding depth (as applicable).
- Plan view of GSI Practice specifying extents of grading and GSI media with northing/easting points and elevations.
- Detail/Section view of GSI Practice specifying depths of each soil and aggregate media layer, referencing material specifications.
- Grading plan shall identify Survey Verification Points along the top and bottom of the side slope, finished surface, and spot elevations of the GSI Practice for contractor verification during construction.

GSI-6 Media Liners

- Detail/Section view of GSI Practice: specify media liner type, horizontal and vertical extents within the section, and category/class or manufacturer.
- Anchoring detail for media liner.

GSI-7 Landscaping

- Tree protection plan per the requirements outlined in GSI-7.8.
- Existing tree protection detail GSI-7.8.
- Planting plan per the requirements outlined in GSI-7.10
- Planting details per GSI-7.3, GSI-7.4 and GSI-7.5.
- Temporary irrigation identified for vegetation establishment with watering source, connection, and distribution method identified, along with plans for removal of the temporary irrigation.

GSI-8 Piping

- Specify in-situ infiltration testing locations and frequency for all GSI Practices. Reference Specification Section 02956 Green Stormwater Infrastructure In-situ Infiltration Testing for recommended test methodology.
- Plan view of GSI Practice indicating location of all piping components including northing/easting, invert elevations , and stationing (as applicable).
- Profile view of pipe lengths, size, material, and installed surface and invert elevations (as applicable).
- Pipe capacity, design flow rates, maximum velocity calculations, and hydraulic grade line elevations (if required to include on the design plans by the approving jurisdiction).
- Detail of anchoring design to prevent flotation (as applicable).
- Detail of connection to GSI outlet or downstream drainage system (as applicable).

GSI-9 Outlets

- Plan view of GSI Practice indicating location of outlet structure(s) including northing/easting points and RIM elevations.
- Spot elevations to show positive drainage path towards the outlet structure(s) as well as major overland flow paths and bypass for storm events that exceed the design capacity of the GSI Practice.
- Detail/Section view of outlet structure (s) specifying recommended product/manufacturer, structure size, dimensions, and elevations of overflow mechanisms including structure top, flow control weir/orifice/ valve, and inverts (as applicable).
- Detail of anchoring design to prevent flotation (as applicable).
- Maximum outflow rate and drawdown time calculations.
- Detail of outlet structure connection to downstream drainage system.

GSI-10 Storage Chambers

- Specify in-situ infiltration testing locations and frequency for all GSI sites. Reference Specification Section 02956 Green Stormwater Infrastructure In-situ Infiltration Testing for recommended test methodology.
- Storage capacity calculations including tributary drainage area, impervious tributary area, required retention volume (RRV), storage chamber and aggregate component storage volume, and storage volume provided by retention practices (V_R) (as applicable).
- Calculations or manufacturer’s certification stating that the system meets the required design loading requirements.

- Plan view of GSI Practice specifying extents of subsurface storage with northing/easting points and elevations.
- Grading plan shall identify Survey Verification Points along the top and bottom of the side slope, finished surface, and spot elevations of the GSI Practice for contractor verification during construction.
- Detail/Section view of GSI Practice specifying type, spacing, and/or layout of subsurface storage, with depth of aggregate media layers (as applicable), referencing material specifications.
- Detail of anchoring design to prevent flotation (as applicable)
- If propriety system is used, design shall reference to manufacturer's standards and specifications
- Specify depth or elevation within storage chambers for which 10% of the total storage volume is met, and specify contractor demarcation of depth on installed chamber to clearly indicate the depth of sediment accumulation at which clean-out is required.

GSI-11 Internal Control, Protection, & Stabilization

Site Activity Management Plan and Detail Drawing(s), including:

- Plan view(s) showing extents of each GSI Practice and surrounding site
- Existing contours and existing drainage paths or flow arrows
- Proposed contours and proposed drainage paths or flow arrows
- Delineation of GSI boundaries with callouts for type of GSI Practice, name of GSI Practice, and reference to relevant site plan drawing(s)
- Callouts for GSI Components within each GSI Practice requiring control and protection
- GSI areas requiring control and protection measures and limitations on use of those areas throughout construction
- Types and locations of control and protection measures
- Details of control and protection measures, including acceptable material and installation
- Delineation of Tree Protection Zones outside of the GSI
- Notes describing maintenance requirements for control and protection measures, including timing for installation, replacement, and permanent removal
- Construction phasing and sequencing relative to the GSI facility(ies) including temporary irrigation requirements for vegetation establishment considering watering source, connection, distribution, and removal.

5610.4 Specification Requirements

The specifications tell the contractor how to build the project. The **Project Manual** consists of the written documents for procuring and constructing the project, including but not limited to the bidding documents, the agreement, bond forms, general conditions, supplementary conditions, and technical specifications. The designer is responsible for including any jurisdiction-specific standard specifications applicable to the project, utilizing the GSI Construction Specifications (**Appendix H**), and preparing additional technical specifications as needed. The designer is also responsible for coordinating all technical specifications with the front-end specifications in the project manual for continuity of requirements referenced throughout.

A. Jurisdiction Standard Specifications

This manual provides guidelines and tools that are generalized for the MARC region. It is the designers responsibility to coordinate with the **approving jurisdiction** to include all jurisdiction-specific standard specifications and requirements.

B. GSI Construction Specifications

The GSI Construction Specifications can be found in **Appendix H**. The GSI Construction Specifications are structured as guide specifications and it is the designer's responsibility to include all applicable specification sections for the project and provide all required input fields included within each section. .

The purpose of this subsection is to provide a high-level overview of the GSI Construction Specifications so that designers and contractors will have an understanding of the technical contents and the expectation for use. For every project where the GSI Construction Specifications are incorporated into the contract documents, the expectation is for both the designer and the contractor to comprehensively understand the specifications and apply them to all aspects of the project.

The GSI Construction Specifications reference the Kansas City Metro Chapter APWA Specifications (version referenced in Part 1.4 of each specification) exclusively, to provide applicability throughout the region to a wide array of project integration. In general, each specification follows this format:

Part 1: General	Part 2: Products	Part 3: Execution
1.01 Purpose 1.02 Measurement & Payment 1.03 Related Sections 1.04 Reference Standards 1.05 Submittals 1.06 Quality Assurance 1.07 Quality Control 1.08 Delivery, Storage & Handling	• Specific to each GSI Component • Materials required to build each GSI Component • Included as decision points so designer can choose material applicable to the project	3.01 Preparation 3.02 Installation 3.03 Tolerances 3.04 Disposal of Material 3.05 Protection 3.06 Maintenance 3.07 Post-Construction Testing 3.08 Warranty

When to Use GSI Construction Specifications

GSI Construction Specifications included with this manual may be used on projects that include any of the **GSI Practice**s or **GSI Components** defined by this manual. These specifications should work in conjunction with standard and technical specifications; they do not replace the jurisdiction's standard specifications.

The GSI Construction Specifications provide the technical parameters for construction of the GSI Components included with this manual. In addition, they provide definition for protecting and maintaining the GSI during construction and through the establishment period. Infiltration testing protocols are also included. It is the designer's responsibility to incorporate the GSI Construction Specifications and identify other technical specifications that are needed to construct the GSI Practice.

GSI Component Specifications

The GSI Construction Specifications are provided for and correlate with the GSI Components. If a component is included in the project design, the construction specification should also be included in the Project Manual, or the designer should provide an alternative supplemental technical specification. Not every component will be used on every project and the designer should select only specifications applicable for their project.

GSI Construction Specifications - General (All Projects)

There are five (5) GSI Construction Specifications that are not directly associated with a GSI Component. These specifications assist in further direction related to GSI Practice construction planning, execution, testing protocols, and maintenance requirements from the time of installation of the first GSI Component through the Establishment Period. These specifications are highly recommended for consideration on all projects incorporating GSI Practices. If these specifications are omitted from the Project Manual, designer must update references and requirements within the remaining GSI Construction Specification sections accordingly.

02937 Green Stormwater Infrastructure Site Activity Plan

The purpose of the Site Activity Plan is to thoroughly plan construction sequencing, site preparation (including control of stormwater within the site and protection of GSI Practice), installation, stabilization of all disturbed area, and establishment of GSI Practices. The designer is responsible for filling out project and design-specific information for the Site Activity Plan that become spart of the technical specifications. The Site Activity Plan should then be completed and submitted by the contractor and approved prior to starting any construction activities. The Site Activity Plan then functions as a living document that should be updated monthly to reflect changes in construction conditions.

The contractor can work directly with the designer to develop the material required for the Site Activity Plan. Standard forms have been created to assist both designer and contractor with development of the Site Activity Plan, and are included in **Appendix H** along with instructions on how to use the forms. The items required in the Site Activity Plan supplement those required in typical front-end specifications, with an emphasis on proactively constructing with the integrity of the GSI in mind. The following items are the major submittal requirements of the Site Activity Plan:

Green Stormwater Infrastructure Construction Schedule. The GSI Construction Schedule can be included as part of the overall project construction schedule required per the contract documents. The

GSI Construction Schedule should include additional detail on GSI phasing with an emphasis on protecting the GSI Practice, including GSI preparation, installation, and post-construction measures. The following items should be included as part of the GSI Construction Schedule:

- Procurement of GSI materials, including planting materials, lead times, and storage requirements;
- Installation of GSI Components, as defined in this manual;
- Sequence for bypassing/diverting stormwater runoff from GSI facility for establishment of landscape;
- Sequence for site stabilization activities of areas upstream of GSI;
- Inclusion of GSI Establishment, including landscaping showing that the contractor plans to meet the contractual requirements given the required planting windows.

Appendix H includes a template for the GSI construction schedule as well as instructions for both the designer and contractor on how to fill out the form. The contractor may instead elect to include the detailed GSI Component items in their overall construction schedule. If this is the case, appropriate detail must be included to determine the planned timelines for procurement, installation, stabilization, and establishment for each GSI Component specified in the construction drawings and specifications.

Site Activity Plan: The site activity plan should include a plan view sheet that addresses the management of stormwater runoff within the disturbed area as well as site access and utilization relative to protecting the specified GSI Practice locations. Similarly to an erosion and sediment control plan, the stormwater runoff management plan includes a plan view sheet with appropriate existing and proposed topographic information to fully illustrate drainage patterns on the site throughout construction. It is recommended that the designer integrate the Site Activity Plan with the erosion and sediment (E&S) control plans. Where a typical E&S control plan is concerned about stormwater runoff leaving the site, the Site Activity Plan should focus on the impact of these drainage patterns within the site and their impact on the GSI installation sequence and establishment. The plan should also identify site access, haul roads, delivery of materials, and any temporary access facilities. The approving jurisdiction should evaluate site access plan for compaction and sedimentation impact to the GSI facilities. Where compaction is anticipated, the contractor will provide a plan for decompaction and/or removal and replacement of any soils. Development of the site activity plan should integrate protection measures to protect the integrity of the GSI. The following items shall be included as part of the site activity plan:

- Existing and proposed contours illustrating drainage patterns.
- GSI Practice and component locations including extents of storage footprints.
- A plan for protecting existing trees and vegetation during construction;
- Means and methods to control stormwater runoff and protect the GSI Practice during construction (see **Section 5606**, GSI-11 Internal Control Protection & Stabilization and Specification Section 02938).
- Identification of material storage, laydown/equipment staging, and temporary facility areas with a description of how stored materials will be protected, including maximum storage durations, and a description of how materials will be disposed of (if applicable);
- Installation and maintenance plan for internal control and protection components.
- How stormwater runoff is being routed around or away from GSI Practice during construction, as feasible.
- A plan for maintaining utilities on site during construction;
- A description of the equipment and methods used to backfill with respective materials, in a manner that does not put the function of the GSI at risk.
- Sedimentation removal and repair needs within the GSI footprint, as needed.
- Stabilization of contributing drainage area to the GSI related to install timing of GSI Components and prior to removal of internal control and protection components.

Green Stormwater Infrastructure Maintenance Plan. The GSI Maintenance Plan is a standard form that should include specific maintenance activities to be performed by the contractor during the GSI Establishment Period (discussed in Specification Section 02957). Specific activities and proposed frequency of the activities shall be included. The approving jurisdiction may choose to direct the contractor to use a standard or project specific maintenance manual, if available, and ultimately must approve the maintenance plan. The maintenance plan should be updated as needed if maintenance tasks frequencies need to be adjusted to maintain the required Service Levels of Performance per Specification Section 02957.

Appendix H includes a template for the GSI Maintenance Plan that auto-populates standard tasks associated with each GSI Component used in the design. Instructions are also provided in **Appendix H to** assist both the designer and contractor in filling out the form. The tasks identified in this form should be reflected in the contractor's bid for completion during the GSI Establishment Period.

02938 Green Stormwater Infrastructure Control & Protection

The purpose of the GSI control and protection specification is to provide control of stormwater collection, conveyance and runoff to the GSI Practice(s) within a project area, and to protect the GSI Practice during construction and through establishment. The function of the GSI is most commonly compromised by failure to protect it during construction activities. Therefore, proactively planning for the control of stormwater within the contributing drainage area to the GSI, as well as how to protect the GSI facility itself, can maintain the function of the GSI, reducing the need for repairs after construction which will save the city time and money.

This specification supplements the GSI Site Activity Plan specification and includes the control and protection components that the contractor should use to protect the areas identified in the Site Activity Plan. The requirements of this specification are applicable to any project that incorporates GSI Components, regardless of disturbed land area. The Kansas City Metro Chapter APWA 2150 is a key reference for designers and contractors for materials and methods that could be applicable. Note that the control and protection requirements are in addition to, and do NOT replace erosion and sediment control requirements for the project. It is the intent that the designer will provide clear direction on the drawings as to the area of GSI to protect, contributing drainage area to the GSI for reference, and a proposed phasing plan. GSI-11 Internal Control, Protection, and Stabilization provides additional guidance on control and protection measures including design deliverable requirements for construction drawings that will serve as the base for the GSI Site Activity Plan to meet the requirements of this specification.

02939 Green Stormwater Infrastructure Earthwork

The purpose of the GSI earthwork specification is to provide site preparation, excavation, and grading requirements for infiltration-based GSI facilities where compaction would limit the intended design function. This specification is intended to work with standard specifications for earthwork outside of the designated GSI or areas requiring compaction. Items unique to this specification include:

- Definitions for backfill, clearing/grubbing, excavation, finished grade, settlement, and subgrade, specific to GSI construction;
- Discussion of equipment and method requirements for limiting compaction within the GSI Practice;
- Requirement for finished grade elevation of GSI to be surveyed and elevations submitted for review and approval. A tolerance for this surveyed elevation is defined in the specification. The intent is for the grade to be verified prior to landscaping activities.

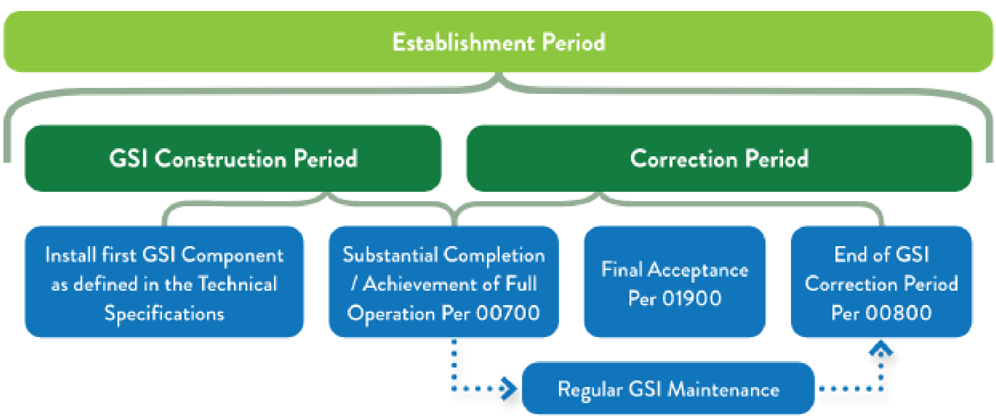
02956 Green Stormwater Infrastructure In-Situ Infiltration Testing

The purpose of the GSI in-situ infiltration testing specification is to provide consistent infiltration testing methods to confirm desired and/or designed drainage of GSI Practice using a double-ring infiltrometer test, a percolation test, a Modified Philip Dunne Infiltrometer, or a permeable pavement infiltration test. The type of test for use on a respective project is a decision point within the specification. Key items of consideration related to this specification include:

- The double-ring infiltrometer test follows the requirements as defined in ASTM D3385.
- The Modified Philip Dunne Infiltrometer Test follows the requirements defined in ASTM D8152.
- Requirements for the percolation test are included in the specification.
- Requirements of infiltration test on porous asphalt or pervious concrete as defined in ASTM C10701/C1701M and permeable pavers as defined in ASTM C1781/C1781M.
- No test may be completed within 24 hours of rainfall exceeding one (1) inch in depth.
- Requirements for implementing the testing pre- and post-construction of GSI Components is referenced in other GSI Construction Specifications.

02957 Green Stormwater Infrastructure Establishment

The purpose of the GSI establishment specification is to define the service and maintenance expectations and activities from the time that the first GSI Component is installed (GSI Construction Period) through the end of the defined Correction Period. It should be noted that the contractor is responsible for the integrity of each GSI Component from the instant that it is installed. The contractor is responsible for proper establishment of all landscaping as specified for each GSI installation. That responsibility includes maintenance activities to preserve the integrity and function of each GSI Component. The contractor is responsible for the integrity and function of the GSI from GSI Construction Period through the defined Correction Period.



This specification provides a minimum level of maintenance service performance expectation for the GSI. This includes minimum service and maintenance performance expectations for the GSI's appearance, handling weeds, pests, and disease, handling mulch and erosion, and maintaining the integrity of drainage within the system. The contractor should reference these performance expectations when developing the GSI maintenance plan required by 02937 Green Stormwater Infrastructure Site Activity Plan.

It is recommended that the Owner complete a final inspection with the contractor within 60 days of the end of the establishment period. This inspection shall identify any deficiencies of the GSI related to the performance expectation and design function. The contractor is responsible for correcting identified deficiencies prior to the end of the establishment period.

How to Use the GSI Construction Specifications

While the GSI Construction Specifications cover the most common and typical GSI Components, they are not all-inclusive and should not limit designers from using alternative products and technologies. If design components are specified for the project that are not included in the GSI Construction Specifications, the designer is responsible for providing the appropriate technical specification for that component. The GSI Construction Specifications guide specifications are considered just that – guides – with only portions of the specification intended to be edited by the designer. The areas of the specifications intended for the designer to tailor for their project are known as "Decision Points."

Decision Points

The GSI Construction Specifications are available in a Microsoft Word file format. Within this file, the designer will find ‘decision points’ designated by text in [brackets]. These are opportunities for the designer to select or include design components, requirements, and direction as appropriate for the project-specific GSI design. All decision points must be made by the designer to appropriately tailor the specification to the project.

The design professional is ultimately responsible for the technical specifications on their project, including the GSI Construction Specifications. If the design professional identifies any technical concerns or disagreement with the GSI Construction Specifications outside of the decision points, they should discuss amendment of the section with the approving jurisdiction.

Notes to Specifier

“NOTES:” to the designer are included throughout each specification to provide guidance through this process. The goal of this approach is to provide enough flexibility to designers to accommodate their unique designs while setting consistent expectations for green stormwater infrastructure construction.

5610.5 Stream Assessment

A stream assessment extends a minimum of one wavelength upstream and downstream of the area to be impacted by construction, or a channel length of at least 20 times the bankfull channel width upstream and downstream of the proposed impact limits, whichever is greater (Figure 5610-5). A stream assessment shall include the components listed in this section. An example submittal is shown in Figure 5610-6 and Figure 5610-7.

Figure 5610-5: Stream Assessment Extents

(Under Development)

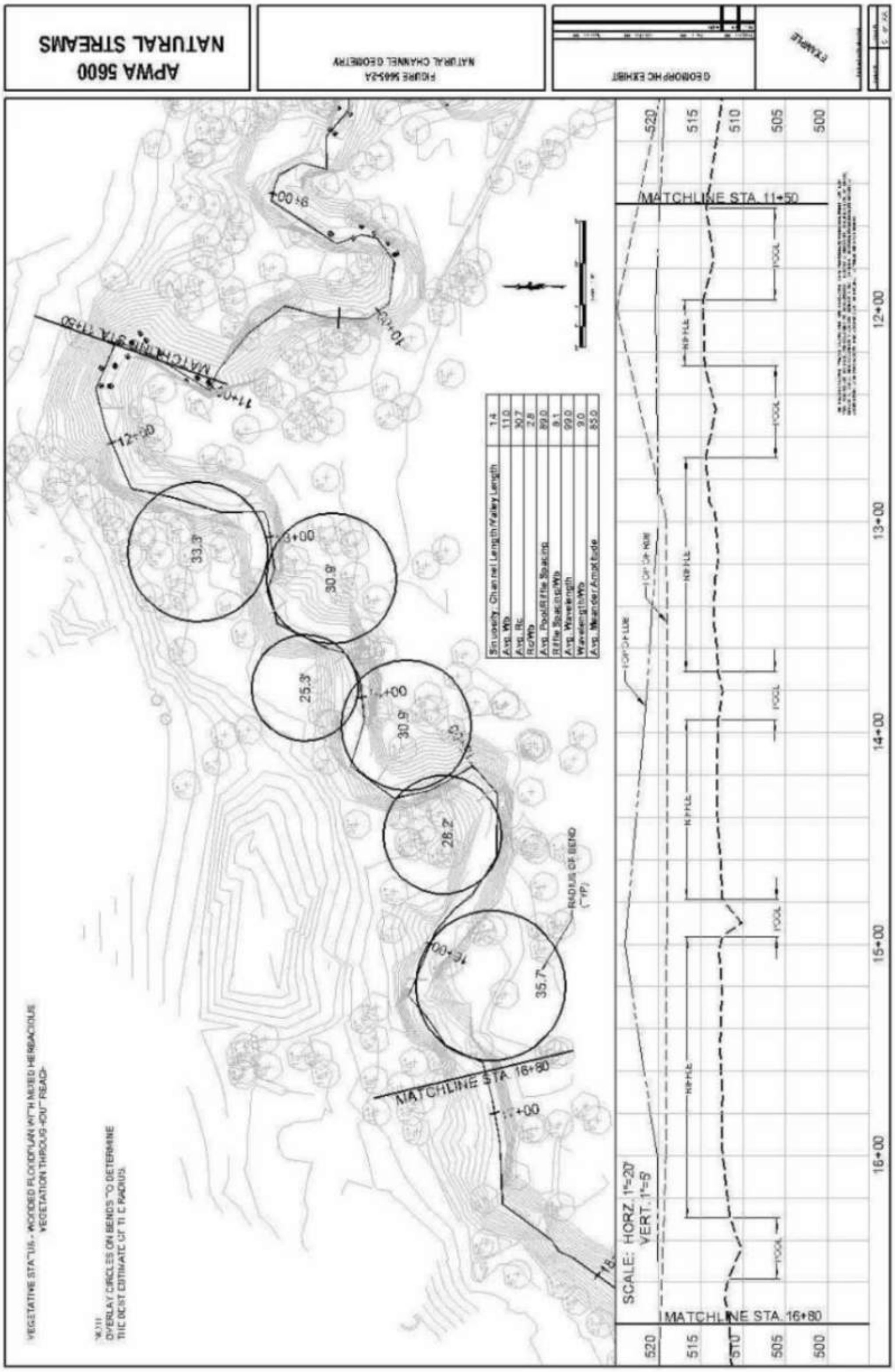


Figure 5610-6: Natural Channel Assessment

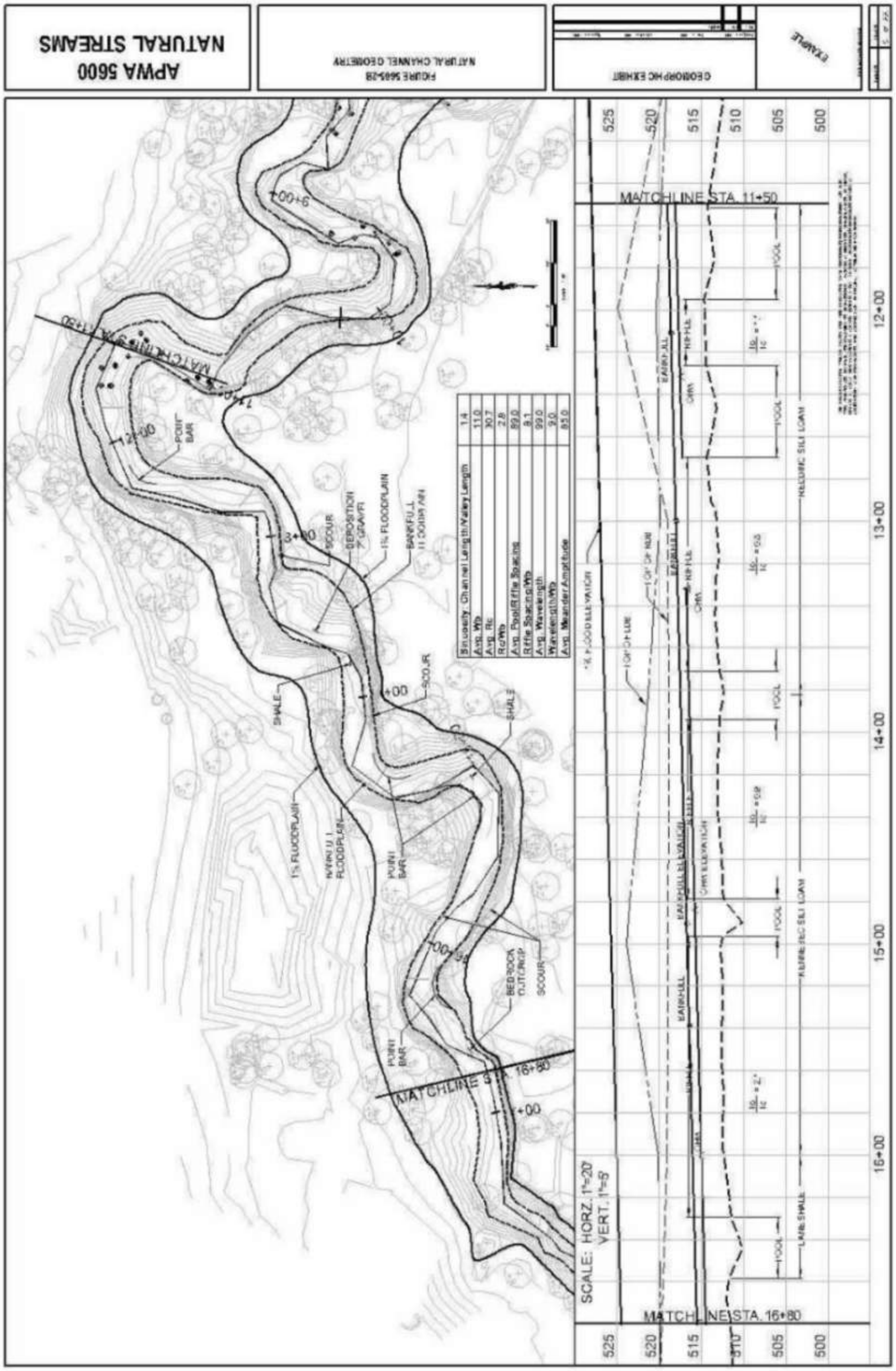


Figure 5610-7: Natural Channel

A. Plan Form Analyses and Inventory:

The plan-view of the natural stream using aerial photographs or planning-level aerial survey shall be plotted to an appropriate scale. The typical plan scales for stream assessments can vary depending on the objectives of the assessment, available resources, and the size and complexity of the stream network being assessed. The following items shall be shown:

- Ordinary high-water mark
- **Top of bank**
- Ground contours at maximum 2-foot intervals (if available). Smaller streams may use 1-foor contours for clarity
- **Bank-full** and floodplain for the 100-year ultimate-conditions storm
- Thalweg, locations of riffles and pools, and spacing between riffles
- Exposed bedrock, areas of differing bed and bank soil or rock materials, and the D50 and shear stress ratio at each riffle
- Active scour and depositional areas, point bars, and islands
- Vegetation within the setback zone (See **Section 5604**)
- Meander length, wavelength, meander amplitude, bankfull width, and radius of curvature for each bend
- Total meander and valley length and sinuosity for the reach
- Photographs of main channel, streamside vegetation, and each riffle, appropriately referenced to plan- view location

B. Bankfull Width, Depth and Discharge

The geomorphic bankfull width, depth, and discharge shall be estimated using field indicators as detailed in Chapter 7 of the USDA's Stream Restoration Design National Engineering Handbook (2007).

- **Unstable and Actively Adjusting Streams:** Where the stream is already unstable and actively adjusting with extreme erosion or sedimentation beyond the range of natural variability, the bankfull conditions are no longer at equilibrium and it is difficult or impossible to conduct correct field determination of bankfull stage. Field diagnosis by a properly trained earth sciences professional under the supervision of the qualified geomorphologist is preferred, but in cases where field indicators cannot be reliably used, bankfull flow shall be estimated as the rural-conditions 2-year design storm flow, and the bankfull width and depth estimated based on the dimensions of that flow through the existing channel. This assumption is intended to provide an upper estimate of the bankfull flow. Regional curves must be peer-reviewed or issued by a federal agency and be developed specific to the project region. For reference, designers may reference the Development and Evaluation of Bankfull Hydraulic Geometry Relationships for the Physiographic Regions of the United States (2015).
- **Upper and Lower Limits**: Decisions predicated on an upper limit should be treated with caution as stream stability has a tolerance of bankfull flow conditions with an upper and lower limit. Weight of evidence approaches are preferred, looking at multiple perspectives for diagnosing bankfull condition when field diagnosis is deemed unapplicable.
- **Regional Curves**: Regressions of the association of bankfull flow and channel dimension versus drainage area within a given hydro-physiographic region, referred to as Regional Curves, can also be used to establish average bankfull condition for stable streams. Some regional curves can also be developed for portions of specific watersheds and at smaller scales for individual rivers and creeks. While often deemed an essential component of natural channel assessment and design, the development and application of regional curves vary in quality and intent, and their use may be subject to approval of the City/County Engineer.

C. Longitudinal Profile

The elevations of the profile along the thalweg shall be field surveyed to the nearest 0.1 ft. and the following features noted: riffles, pools, exposed bed rock, and advancing head cuts (areas of bed elevation change that appear to be actively migrating upstream). The top of left and right bank and any field indicators of bankfull stage. The limits of woody vegetation or top of point bars shall be plotted at correct elevation along the profile. The bankfull flow and the 100-year ultimate storm flow profiles shall be plotted.

D. Cross Sections

One field cross section shall be surveyed through each pool and riffle to intercept the stage occurring at least twice the bankfull depth of the section, and a longer **reference section** shall be surveyed to the limits of the 100-year design storm. The reference section shall be selected at a stable area (if present) and at a riffle that is representative of the overall reach conditions. Cross sections will depict elevations and positions of the channel thalweg, an inner berm (if present), the toe and top of bankfull channel, top of bank (if it differs from bankfull), flood bench, limits of meander belt and/or limits of active alluvial floodplain features, and any floodplain terrace slopes and boundaries contained within the section. At a minimum the pool and riffle sections shall cover the bankfull stage and extend at least two bankfull widths on either side of the bankfull channel or, if the bankfull channel has incised and is entrenched, extend that distance beyond the top of bank. Top of bank and bankfull stage to be depicted on all cross-sections, and the elevation of the 100-year design ultimate conditions storm shall be shown on the reference section.

E. Bed and Bank Materials Analyses

The type of substrates (sediment, rock, woody material, live vegetation) on the bed and banks shall be identified. Bank soils shall be reported by Uniform Soil Classification using the visual-manual procedures (ASTM D 2488). D50, or median particle size, is the particle value at which 50% of the sample's particles are smaller and 50% are larger. The median (D50) particle size shall be determined using the Wolman Pebble Count Method (USDA, 1994, Chapter 11). A shear stress ratio shall be calculated for each riffle based on the applied shear at bankfull flow divided by the critical shear of the D50 particle in the rifle, using methods and tables described in **Section 5608.4.C**.

F. Scour & Critical Shear Stress Analysis

If bed and bank materials are distinct, then the shear stress ratio should be calculated for each. If the shear stress ratio of either stream bed or bank is greater than one, the channel is prone to near-term adjustment and any interventions should be designed to prevent accelerated erosion. If the bed consists of rock, then the shear stress ratio is not applicable unless the rock is prone to fracturing, slaking, or break up, in which case the median size of particle should be used for calculation of the ratio.

For natural channels: The shear stress ratio must be less than one at the extreme downstream point of any development in accordance with the guidelines below.

1. Calculate the average applied shear stress (τ_0) from the hydraulic data as follows:

$$\tau_0 = \gamma RS$$

Where:
γ = the specific weight of water (62.4 pounds per cubic foot)
R = hydraulic radius at bankfull flow in feet
S = the water surface slope along the main channel bankfull, averaging over several bends in the area of the intervention. Effective flow may be calculated using methods described in

USACE's HEC-RAS Hydraulic Reference Manual or may be assumed to be equivalent to the 2-year storm.

2. The critical shear stress (τ_c) is that at which particles in the bed or bank are entrained and scour ensues. Shield's method may be used for calculating the critical shear stress of spherical, noncohesive particles, as follows:

$\tau_c = \theta(\gamma_s - \gamma)D_{50}$
Where
γ_s = the specific weight of sediment
γ = specific weight of water (62.4 lb/ft^3)
D_{50} = the median particle size in the surface layer of bed or banks
θ = the Shield's parameter (0.06 for gravel to cobble, 0.044 for sand)

In lieu of calculated values, the critical shear stress from **Table 5610-3** may be used. Table 5610-3: Shear Stress for Channel Lining Materials presents critical shear for sediment-laden water and where noted, clear water. The designer must exercise judgment as to future conditions. Clear water values may be used below a heavily piped area, concrete channels designed to contain the future flows or immediately below a managed detention pond.

3. Calculate the shear stress ratio:

shear stress ratio = τ_0/τ_c
where
τ_0= average applied shear stress
τ_c= critical shear stress

Table 5610-3: Shear Stress for Channel Lining Materials

Material	Shear Stress (psf)
Granular Material	
Boulders (100 cm)	**20.295**
Boulders (75 cm)	**15.222**
Boulders (50 cm)	**10.148**
Boulders (25.6 cm)	**5.196**
Rip Rap	**3.132**
Cobbles (6.4 cm)	**1.299**
Cobbles and shingles	**1.100**
Cobbles and shingles, clear water	**0.910**
Coarse sand (1mm)	**0.015**
Coarse gravel, noncolloidal (GW), clear water	**0.3000**
Coarse gravel, noncolloidal (GW)	**0.670**
Gravel (2cm)	**0.406**
Fine gravel	**0.320**
Fine gravel, clear water	**0.075**
Fine sand (0.125 mm)	**0.002**
Fine sand (0.125 mm) (SP)	**0.002**
Fine sand, colloidal, (SW), (SP), colloidal	**0.075**
Fine sand, colloidal, (SW), (SP), clear water	**0.027**
Graded loam to cobbles, noncolloidal, (GM)	**0.660**
Graded loam to cobbles, noncolloidal, (GM), clear water	**0.380**
Graded silts to cobbles, colloidal (GC)	**0.800**
Graded silts to cobbles, colloidal, (GC), clear water	**0.430**
Fine Grained	
Resistant cohesive (CL), (CH)	**1.044**
Stiff clay, very colloidal, (CL)	**0.460**
Stiff clay, very colloidal, (CL), clear water	**0.260**
Moderate cohesive (ML-CL)	**0.104**
Ordinary firm loam (CL-ML)	**0.150**
Ordinary firm loam, (CL-ML), clear water	**0.075**
Alluvial silts, colloidal (CL-ML)	**0.460**
Alluvial silts, colloidal, (CL-ML), clear water	**0.260**
Alluvial silts, noncolloidal (ML)	**0.150**
Alluvial silts, noncolloidal, (ML), clear water	**0.048**
Sandy loam, noncolloidal (ML)	**0.75**
Sandy loam, noncolloidal, (ML), clear water	**0.037**
Silt loam, noncolloidal (ML)	**0.110**
Silt loam, noncolloidal (ML), clear water	**0.048**
Shales and hardpans	**0.67**
Others	
Jute net	**0.46**
Plant cuttings	**2.09**
Well established dense vegetation to normal low water	**2.16**

Material	Shear Stress (psf)
Geotextile (synthetic)	**3.01**
Large Woody Debris	**3.13**

Note: For non-cohesive soils, the table values are based on spherical particles and Shield equation, as follows: $\tau c = \Theta(\gamma s - \gamma) D$ where γs is the specific weight of sediment (165 pcf), γ is specific weight of water, D is the reference particle size, and Θ is the Shield's parameter (0.06 for gravel to cobble, 0.044 for sand). For cohesive soils the values are based on limited testing as reported in Chow (1988) and USDA (2001).

G. Plan-Form Ratios

The following ratios shall be calculated, and those that lie outside the typical range shall be noted. Streams are highly variable and ratios outside these ranges do not necessarily indicate problems.

Table 5610-4: Plan-Form Ratios

2.0 RATIO	3.0 TYPICAL RANGE
4.0 Meander length / Wavelength (sinuosity)	5.0 1.1 to 1.5
6.0 Meander length / Bankfull width	7.0 10 to 14
8.0 Radius of curvature / Bankfull width	9.0 2 to 5
10.0Riffle Spacing / Bankfull width	11.05 to 7

H. Channel Condition Scoring Matrix

The channel condition scoring matrix given in **Table 5610-5** shall be completed for natural channels. A rating of 12 indicates a stream of moderate stability that will likely require only standard levels of protection during construction. A rating between 12 and 18 indicates that special measures may be necessary to address those issues rated as poor in the assessment. Natural channels with a rating greater than 18 may exhibit significant system-wide instability. These natural channels should be studied in more detail by experts in river engineering and fluvial geomorphology.

Table 5610-5: Channel Scoring Matrix

(Under Development)