Section 1 – Policies and Procedures

Section 2 – Construction Management Practices

Section 3 – Temporary Construction Site Runoff Management Practices

Section 4 – Permanent Erosion Prevention and Sediment Controls

Section 5 – Permanent Stormwater Treatment Controls

Section 6 – Industrial & Commercial Runoff Management Practices

Section 7 – Other Source Controls

Section 1 – Policies and Procedures

1 Introduction

1.1 Background and Purpose

New developments and redevelopments typically increase the amount of impervious area on a site which affects the flow of water as it rains by increasing the volume and rate of stormwater runoff. If not properly managed, increased peak flows and volumes could result in flooding and channel erosion. In addition, typical stormwater runoff from urban sites contains pollutants such as litter, sediment, oils and greases, nutrients and metals, bacteria, fertilizers and debris. These pollutants are commonly transported through municipal separate storm sewer systems (MS4s), from which they are often discharged untreated into local waterbodies. The City of Franklin has been designated by the U.S. Environmental Protection Agency (EPA) as a small MS4, and urbanized areas like the City of Franklin are required under Federal and State law, through the National Pollutant Discharge Elimination System (NPDES) Phase II Rule, to develop a stormwater management program in order to reduce the discharge of these stormwater pollutants and to achieve the stormwater treatment goals set forth by the U.S. EPA. The City of Franklin's Stormwater Management Ordinance gives authority to this Stormwater Management Manual in its municipal code.

> **Therefore, all new development and redevelopment within the City of Franklin must design, install and maintain stormwater quantity and quality controls as set forth within this Stormwater Management Manual as part of the City of Franklin's stormwater management program.**

The State of Tennessee NPDES MS4 Permit requires the development and implementation of permanent (post-construction) stormwater controls comprised of runoff reduction and pollutant removal from new development and redevelopment projects that disturb one acre or more. The Runoff Reduction Method (RRM) is the preferred control practice as it can achieve both volume control and pollutant removal. Site design standards require, in combination or alone, management measures that are designed, installed and maintained to infiltrate, evapotranspire, harvest and/or use, at a minimum, the first inch of every rainfall event preceded by 72 hours of no measurable precipitation. The first inch of rainfall must be 100% managed with no stormwater runoff being discharged from the site. For projects that cannot meet 100% of the runoff reduction requirements, the remainder of the stipulated amount of rainfall must be treated prior to discharge with a technology expected to remove 80% total suspended solids (TSS) in order to meet water quality requirements.

This Stormwater Management Manual has been compiled by the City of Franklin to assist planners, developers, contractors and various businesses and industries in complying with the guidelines set forth by the NPDES Phase II Rule. This manual is designed to support the stormwater management language set forth within the Ordinance by way of providing specific guidance for selection of Best Management Practices (BMPs) and elaborating on various practices. This manual will assist the City of Franklin in stormwater pollution prevention and water quality protection through impact-reducing site design, BMP selection, construction management, post-construction management, and good housekeeping measures.

1.2 How to Use This Manual

This Stormwater Management Manual contains the following sections:

Section 1 provides an introduction to the NPDES MS4 Permit requirements and the City of Franklin's stormwater management program. This section discusses the principles of site layout and the policies and procedures for selecting and designing water quality and water quantity controls required for all new development and redevelopment within the City. This section also presents an introduction to Low Impact Development (LID) design and Green Infrastructure Practices (GIPs).

Section 2 contains construction management practices (CP) that should be used for contractor and construction site operations. These management practices focus on good housekeeping measures and capturing pollutants from typical contractor and construction site activities.

Section 3 contains temporary construction site runoff management practices (TCP) that are consistent with those described in TDEC's Erosion and Sediment Control (E&SC) Handbook. The NPDES MS4 Permit requires the development and implementation of temporary construction site stormwater controls. This section provides guidance on the BMPs that have been approved for use by the City of Franklin.

Section 4 contains permanent erosion prevention and sediment control (PESC) measures which should be selected during the early planning phase of a project and included in the initial site design.

Section 5 contains permanent stormwater treatment controls (PTP) that are focused on green infrastructure practices and accepted 80% TSS treatment controls. These management practices should be selected during the site layout and early planning phase of the project in order to achieve the required runoff reduction.

Section 6 contains industrial and commercial treatment practices (ICP). These practices are similar to the construction management practices found within Section 2, but are intended for use in an industrial environment rather than on a construction site.

Section 7 contains other source control measures (SC) that predominately focus on the management of hazardous materials. These measures can be used in addition to the construction management practices and the industrial and commercial practices.

When planning and designing a site for development or redevelopment within the City of Franklin, this manual is best used in the order shown in Figure 1.

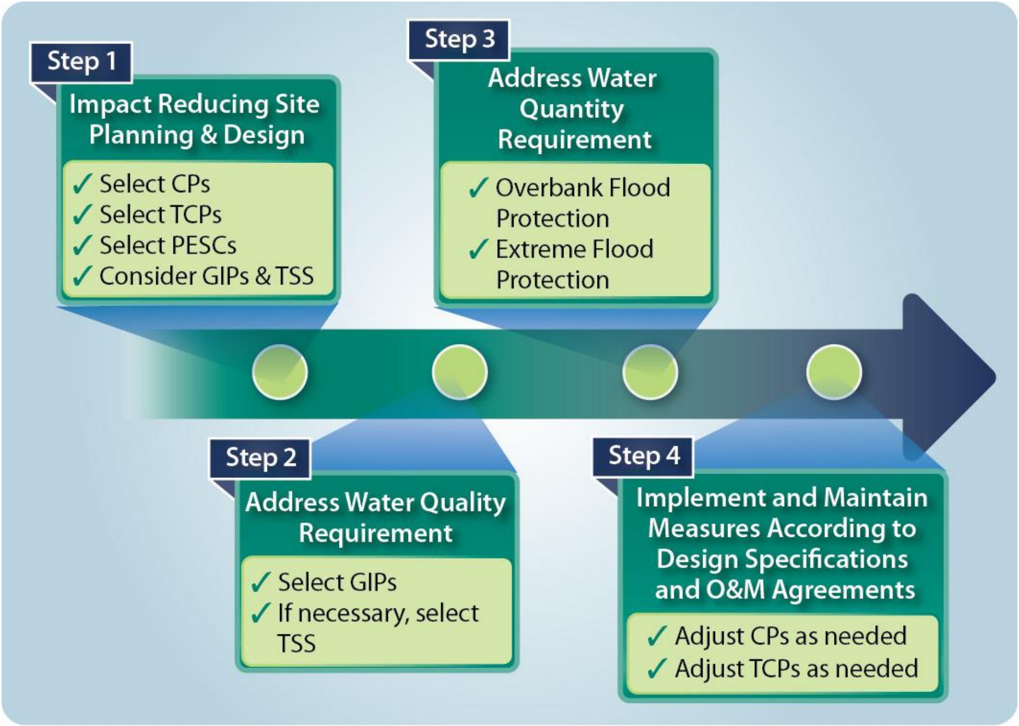


Figure 1 – Site Planning and Development Process

The fact sheets in this manual are designed for easy reference. They are categorized, focused, and concise to allow easy access and expedient use. Each fact sheet can be used as a stand-alone document that may be distributed to facilitate focused discussion about design and/or implementation of each management practice. However, the goals of Franklin's stormwater management program will not be met by simply installing BMPs. This manual is intended to guide the design of a project from start to finish, and stormwater management should be part of the site design considerations in the initial phase of conceptual design. There are some BMPs that require structural practices, though many are non-structural practices where everyday activities may be performed in a manner that limits the impact of stormwater runoff to surface water quality.

1.3 Sources of Pollution and Its Impacts

General Pollution Overview

Pollution entering Franklin's streams and channels has many sources and entry paths. Pollutants are generally either washed into surface waters by rainfall runoff or they enter through human activities such as connecting non-stormwater drains to the stormwater drainage system or by someone dumping waste into drains or streams directly. Franklin has programs of education, prevention and inspection to address the illicit connections or illegal dumping by individuals. This manual articulates Franklin's standards to reduce rainfall runoff of pollutants into our natural stream system.

Rainfall induced pollution enters primarily by two methods. The first is erosion and sedimentation (deposition) of sediment and the pollutants sediment contains. The second is the simple washoff of pollution that may lie on paved (impervious) surfaces. The following briefly describes these two general pollution sources.

Erosion and Sedimentation Overview

Short-term stormwater quality management predominately focuses on E&SC for construction sites; however, E&SC can also be a concern for fully developed sites. Soil erosion is the process by which soil particles are removed from land surfaces by wind, water or gravity. Natural erosion generally occurs at slow rates. However, the rate of erosion increases when land is cleared or altered and left disturbed. Erosion rates will increase when flow rates and velocities discharged from a site exceed the erosive range.

Clearing and grubbing activities during construction remove vegetation and disrupt the structure of the soil surface, leaving the soil susceptible to rainfall erosion, stream and channel erosion, and wind erosion if left untreated. Ultimately, the material suspended by erosion settles during sedimentation in downstream reaches.

Once eroded, soil particles may travel anywhere from a few inches to many miles before gravity causes them to settle. The settling of soil particles is a process known as sedimentation. Excessive levels of sedimentation can create problems such as clogging of storm drains, blockage in streams and channels, damage to existing habitat, and in some cases, formation of habitats in undesirable locations.

There are negative influences on channels, streams and rivers when sediment enters the waterways. As sediment volumes increase in waterways, the overall capacity decreases. This causes an increase in flooding as well as creates excessive maintenance needs.

1.3.1 Water Erosion

Rainfall events begin the water erosion process by dislodging minute soil particles. These soil particles then become suspended in the water droplet. The sediment laden water droplets accumulate on the soil until a sufficient quantity has developed to begin flowing under the forces of gravity.

The initial flow of sediment laden water generally consists of a thin, slow-moving sheet, known as sheet flow. In most cases, sheet flow does not prove to be highly erosive; however, it does begin the transport of the sediment that was previously suspended. Irregularities in soil surface and uneven topography will usually cause sheet flow to become concentrated into rivulets where flow causes an increase in velocity and erosive energy. This increase in erosive energy of water flowing in rivulets creates small grooves, or rills, in the soil surface.

Rill erosion of the soil surface concentrates flows, which increases flow velocity and erosive energy due to gravitational forces. This results in deeper and wider rills that may join together with adjacent rills. Typically, rills run parallel to the slope and each other. In addition, rills are small enough to be stepped across, and are usually enlarged by direct erosion of the rill's sides and bottom by the action of flowing water.


Severe Gully Erosion

The joining together of several adjacent rills, or sufficient enlargement of a single rill, begins gully erosion. In most cases gullies run parallel to the slope and may have one or more lateral branches. Gullies are enlarged by the following four key actions:

1. Gullies often have a "head cut" at the upstream end, which progresses its way upstream as water flowing into the gully erodes away the lip of the head. A waterfall working its way upstream can exemplify this. This can be seen in the picture above.
2. The flow in a gully tends to undercut the banks. Once the banks are sufficiently under cut, the banks will collapse into the gully where the collapsed soil is then washed away.
3. The collapse of banks into the gully causes flowing water to be diverted around the temporary blockage of soil. This temporary blockage of soil increases the velocity along one or both banks, which results in increased bank erosion.
4. The concentration of flows in the gully may result in scour of the gully floor until a stable slope is obtained.

1.3.2 Stream and Channel Erosion

Construction activities often require the disturbance of streams and channels. Once vegetation or other bank protection measures are disturbed, flows may begin to erode the unprotected soil.

Construction activities often result in the disturbance of channel and stream flow. However, this should only happen when traversing banks such as a temporary channel and stream crossing, culvert installation, bridge construction, etc. By diverting flows within the channel, velocities are generally increased in some areas to compensate for decreases in other areas. The increase in velocity may exceed those normally experienced by the channel, resulting in bank erosion and bottom scour.

Construction activities and the construction of facilities that increase the quantity and rate of runoff as well as how runoff is conveyed often increases the quantity and flow rate to streams and channels. The increased quantity and rate of flow can cause bank erosion and bottom scour.

1.3.3 Wind Erosion

Dust is defined as solid particles or particulate matter small enough to remain suspended in the air for a period of time and large enough to eventually settle out of the air. Dust from a construction site originates as inorganic particulate matter from rock and soil surfaces and material storage piles. The majority of dust generated and emitted into the air at a construction site is related to earth moving operations, demolition, construction traffic on unpaved surfaces, and wind over disturbed soil surfaces.

1.3.4 Factors Influencing Erosion

There are five primary factors that influence erosion: soil characteristics, vegetative cover, topography, climate, and rainfall.

Soil Characteristics – Particle size, particle gradation, organic content, soil structure, and soil permeability are all characteristics that contribute to the determination of a soil's erodibility. These characteristics affect the stability and infiltration capacity of the soil. Less permeable soil has an increased risk of runoff and erosion. Typically, soils that contain high percentages of silts and clays are the most erodible.

Channel flow is also affected by soil characteristics in that tractive-force or shear stress developed by flowing water over the channel banks and bottom may cause soil particles to move and become suspended into the runoff. The "permissible shear" stress indicates the stress that the channel banks and bottom can sustain without jeopardizing stability. It is possible to increase the allowable shear stress in the channel by utilizing "soft/green" or "hard" armoring on the channel bottom and banks.

Vegetative Cover – Vegetative cover creates an erosion shield by stabilizing the soil. In addition, vegetative cover protects soil from direct rain, and also decreases the velocity of runoff. This allows greater infiltration as well as maintains the soil's capacity to absorb water. Vegetative root structures create a favorable soil structure, improving its stability and permeability.

Topography – Slope is a key element in determining the volume and velocity of runoff. An increase in the slope length, and/or steepness causes an increase in the runoff rate, and consequently, an increase in the potential for erosion.

Climate – High precipitation areas as well as areas with freeze/thaw cycles have significant effects on soil stability and structure.

Rainfall – Frequency, intensity, and duration are fundamental factors in determining the amounts of erosion produced. In Tennessee, the erosion risk period is typically highest in the wet season (typically December through May), which coincides with a period of minimal vegetative cover.

Pollution Washoff Overview

There are a number of pollutants that wash off into streams. The following describes the most common.

1.3.5 Nutrients

Fertilizers, pesticides, construction chemicals, and solid waste contain phosphorus and nitrogen, which can result in excessive or accelerated growth of vegetation or algae. This increase in vegetation results in the impairment of lakes and other water resources and the growth of algae results in the depletion of dissolved oxygen, potentially resulting in fish kills.

1.3.6 Oxygen Demanding Substances

The biological decomposition of organic matter in stormwater depletes the amount of dissolved oxygen (DO), which causes biochemical oxygen demand (BOD). BOD measures the degree of dissolved oxygen depletion by expressing the amount of easily oxidized organic matter present in water. In addition, certain non-organics materials in the water can intensify DO depletion.

1.3.7 Metals

Artificial surfaces such as galvanized metal, paint, or preserved wood contain metals that can enter stormwater as their surfaces corrode, flake, dissolve, decay, or leach. These metals that are found in urban stormwater often originate from passenger vehicles. Over half the trace metal load carried in stormwater is associated with sediments to which these eroded metals attach. Heavy metals are of concern because they are toxic to aquatic organisms, can be bioaccumulative, and have the potential to contaminate drinking water supplies.

1.3.8 Pesticides

Pesticides are herbicides, insecticides, and rodenticides that are commonly used on construction sites, lawns, parks, golf courses, etc. Excessive or improper application of theses pesticides may result in direct water contamination, indirect water pollution by aerosol drift, or erosion of treated soil and subsequent transport into surface waters.

1.3.9 Oil, Grease, and Fuels

These products are widely used and may spill, leak, or be dumped on the ground where they can wash into waterways. Sources include leaks during normal vehicle use, hydraulic line failure, spills during fueling, and inappropriate disposal of drained fluids. These products can cause harm to plant and animal life.

1.3.10 Other Toxic Chemicals

Synthetic organic compounds such as adhesives, cleaners, sealants, and solvents are often improperly applied, and may also be improperly stored and disposed of. Accidental spills, improper storage or deliberate dumping of these chemicals onto the ground or into storm drains causes environmental harm to receiving waters.

1.3.11 Miscellaneous Wastes

Miscellaneous wastes include wash water from concrete mixers, paints and painting equipment cleaning activities, solid organic wastes resulting from trees and shrubs removed during land clearing, wood and paper materials, food and containers, such as paper, aluminum, and metal cans, industrial or heavy commercial process wash/cooling water, vehicle washing, other commercial or industrial wastes and sanitary wastes.

2 Principles of Managing Stormwater Quality and Quantity

Successful and effective stormwater management is a two-fold process: one management principle is related to the quality of runoff and the potential pollutants that can be carried within stormwater runoff and deposited untreated into local surface waters; the other is related to the increased quantity of stormwater runoff and related flooding and maintenance issues. Stormwater volume in itself is a potential trigger for stormwater pollution as an increase in the volume of stormwater runoff can also increase the likelihood for pollutant transport and channel erosion.

An increase in development has led to an increase in impervious area and therefore an increase in runoff volume, flow rate and pollution. Stormwater quality management involves reduction of runoff volume and appropriate treatment of any polluted stormwater that that does run off. Stormwater quantity management involves slowing, detaining, and/or controlling the volume and flow rate of runoff from "major" storm events ranging from the 2 to the 500-year statistical storm frequency.

Communities are increasingly moving towards Green Infrastructure Practices (GIPs) – or a combination of green and conventional stormwater management practices – to manage stormwater. Green Infrastructure (GI), as used in this Manual, is a term that refers to a subset of Low Impact Development (LID) structural systems and practices that support the principles of LID and make use of volume-reducing designs and calculations. Green Infrastructure systems are an innovative approach to urban stormwater management that do not rely on the conventional end-of-pipe structural methods. Rather, they are an ecosystem-based approach that strategically integrates stormwater controls throughout an urban landscape to attempt to maintain a site's pre-development conditions. Targeted community or watershed goals and objectives are addressed through the use of structural and non-structural techniques such as permeable pavement, bioretention/rain gardens, rain barrels, and public outreach.

This chapter discusses the principles of managing stormwater quality and quantity. The technical details for designing for stormwater quality and quantity requirements are described in Chapters 3 and 4 of this section, respectively.

2.1 Introduction to Green Infrastructure Practices

The overall goal of GIPs is to reduce stormwater runoff volume and to treat pollutant loads close to the source where they are generated. In doing so, GIPs provide many stormwater management benefits; such as improved water quality, flow management, groundwater recharge, and channel protection. GIPs minimize the hydrologic impacts of urban development on the surrounding environment by intrinsically linking stormwater management to urban design and landscape architecture. This is accomplished with appropriate site planning and through the direction of stormwater towards small-scale systems dispersed throughout the site. These systems should be carefully selected based on the site's topographic and climatic conditions. Correctly pairing land uses with GIPs is an important first step in site planning. GIPs, located in Section 5, should be matched with land use and setting, as listed in the GIP criteria fact sheets and detailed in each GIP discussion.

Why Green / Low Impact Development

Current development patterns and traditional storm water management techniques have resulted in large amounts of impervious surfaces in cities across the country. Conventional development approaches to stormwater management often use practices to quickly and efficiently convey water away from developed areas. This results in larger volumes of runoff flowing directly to channels, streams, rivers and combined sewer systems as well as any pollutants contained in the runoff.

In contrast, LID utilizes a system of source controls and small-scale, decentralized treatment practices to help maintain the hydrologic function of the landscape by allowing water to infiltrate, evapotranspire, or be reused onsite. The conservation of open space, the reduction of impervious surfaces, and the use of small-scale storm water controls, such as green roofs, are just a few of the LID practices that can help maintain predevelopment conditions and keep greater volumes of runoff from routing to the stormwater system. LID techniques can offer the following many benefits to the City of Franklin:

Community

- Protect flora and fauna
- Balance growth needs with environmental protection
- Reduce municipal infrastructure and utility maintenance costs (streets, curbs, gutters, sidewalks, storm sewers)
- Encourage private sector participation in green stormwater infrastructure at residential, commercial, and industrial facilities
- Decrease flooding risks for small storms
- Create attractive, natural and multifunctional public spaces

Developers

- Reduce land clearing and grading costs
- Potentially reduce infrastructure costs (streets, curbs, gutters, sidewalks)
- Reduce storm water management costs
- Potentially reduce municipal permitting fees and increase lot yields
- Increase lot and community marketability

Environment

- Preserve integrity of ecological and biological systems
- Protect site and regional water quality by reducing sediment, nutrient, and pollutant loads to water bodies
- Reduce impacts to terrestrial and aquatic plants and animals
- Preserve trees and natural vegetation
- Mitigate the heat island effect and reduce energy use

2.2 Introduction to Best Management Practice Selection

Stormwater management measures must be applied in the form of structural and non-structural BMPs as detailed within this manual. This section is in two parts. Temporary BMPs are designed to address construction activities, while permanent BMPs are designed to address long-term stormwater management objectives. Effective planning for both short and long term goals allows for an easy transition from temporary to permanent controls and favorable results with respect to cost and performance. Each unique project has specific risks that can be addressed through properly selected BMPs. In order to reach this goal, specific project risks must first be identified, BMP objectives defined, BMPs determined, and lastly the appropriate BMPs selected.

Define BMP Objectives

The initial step in the selection and use of BMPs is to define objectives. BMP objectives must address development and construction activities as well as existing industry, businesses, and private parties whose activities may contribute to overall water quality. These activities are all unique and require specific knowledge of the pollution risks associated with each activity. This knowledge is essential in selecting BMPs effectively. The following BMP objectives supplement the standards set forth by the City's Stormwater Management Ordinance:

1. **Practice Good Housekeeping**: Proper management of pollutant sources and modification of construction activities can prevent pollutants from draining or being transported off-site.
2. **Contain Waste**: Dispose of all construction waste in designated areas, and prevent stormwater run-on and run-off from these areas.
3. **Minimize Disturbed Areas**: Land clearing should take place only in areas that will be under active construction within a few months of the time of clearing. Phased clearing of a large development is recommended. Land clearing during the rainy season should be avoided if at all possible. Sensitive areas such as steep slopes, riparian buffers, and natural watercourses should never be disturbed if at all possible.
4. **Stabilize Disturbed Areas**: Temporary stabilization techniques should be utilized in areas where there are disturbed soils that are not undergoing active construction. Upon final completion of a construction activity, permanent landscaping, and stabilization should be applied.
5. **Protect Slopes and Channels**: Steep and unstable slopes should not be disturbed if they are outside of the approved grading plan area. Runoff should be conveyed from the top of the slope in a safe manner ensuring that the slope is stabilized as soon as possible. Natural channels should not be disturbed if at all possible. Temporary and permanent channel crossings require stabilizing as quickly as possible to ensure that increases in runoff velocity caused by the project do not erode the channel.
6. **Control Site Perimeter:** Upstream runoff should be diverted either around or through the construction project in a safe manner. These diversions should be designed to ensure that downstream property would not be damaged. In addition, all runoff exiting the construction site should be free of excessive sediment, and other pollutants.
7. **Control Internal Erosion:** Sediment laden water should be detained or otherwise treated within the site to avoid potential pollution to water resources.

Site characteristics and specific contractor activities affect the potential for erosion and pollution by other potential pollutants contained in materials and chemicals used on the construction site. While determining BMP objectives, the following factors should be considered:

1. **Site conditions including the following:**

- Soil type, including underlying soil strata that are likely to be exposed to stormwater.
- Natural terrain and slope.
- Final slopes and grades.
- Location of concentrated flows, storm drains, channels, and streams.
- Existing vegetation and ground cover.

2. **Climatic factors including the following:**
   - Seasonal rainfall patterns.
   - Appropriate design storm, which takes into account quantity, intensity, and duration of rainfall.
3. **Type of construction activity.**
4. **Construction schedules, construction sequencing, and phasing of construction.**
5. **Size of construction project and areas to be graded.**
6. **Location of the construction activity relative to adjacent uses and public improvements.**
7. **Types of construction materials and potential pollutants present or that will be brought on-site.**
8. **Floodplain, Floodway, and riparian buffer requirements.**

Determine BMPs

Once the BMP objectives are defined, specific BMPs should be determined. In order to determine the appropriate BMPs to use, a plan for the project will be needed. This plan should contain enough detail that drainage patterns, topography, and existing and permanent stormwater control structures can be located with ease. The plan will be required in order to obtain a Stormwater Management Permit, which is required for all development and redevelopment as identified in the City of Franklin Municipal Code. The plan should identify the following information, in addition to any plan requirements set forth by the Code:

1. Stormwater entrance and exiting locations. Sheet and Channel flow for the existing and final grading contours should be included. This should be in accordance with the master stormwater management plan for the specific watershed.
2. Identify locations of steep slopes and unlined channels that are subject to high rates of erosion. Long, steep slopes over 100 feet in length are considered as areas of moderate to high erosion potential. Soil bioengineering is preferred for stabilization over rip rap, and other hard armoring techniques. (See City of Franklin Municipal Code)
3. Categorize slopes as:
   a. Low Erosion Potential (0 to 5 percent slope)
   b. Moderate Erosion Potential (5 to 10 percent slope)
   c. High Erosion Potential (slope greater than 10 percent)

4. Identify sensitive areas and water resources that should not be disturbed such as wetlands, springs, sinkholes, floodplains, floodways, areas to be used for infiltrative GIPs for post construction, sensitive areas or riparian buffers,including other areas where site improvements will not be constructed. Clearing limits should be identified to prevent disturbance of these areas during construction activities.
5. Identify tributary areas for each outfall location. The approximate area of each tributary should be calculated.
6. Identify locations where contractor activities may have a risk of causing a runoff or polluted discharge. (See Section 2, Construction Management Practices, for additional information.)

This plan will allow easy identification of BMPs that need to be considered on a particular construction project. Planning prior to the commencement of construction and phasing construction activities always prove to be more cost effective than treatment of stormwater after the fact. Preventative maintenance is simpler and less costly than correcting a problem that has already occurred.

Once BMP objectives have been determined, the BMP selection process illustrated in Figure 2 below should be utilized. The BMP selection process is used to determine the BMP objectives that will be met by the various BMPs. Many BMPs can achieve more than one objective, which should be taken into account during the selection process. This allows for selecting the most cost-effective BMP. For example, it is not always necessary to install extensive sediment trapping controls during construction. In fact, sediment trapping should be used only as a short-term measure for active construction areas, and replaced by permanent stabilization measures as soon as possible. However, it should be noted that perimeter/outfall control in the form of permanent detention ponds should be built first and used as temporary sediment control during construction. After construction is complete and the tributary area is stabilized, the permanent outlet configuration can be reestablished.

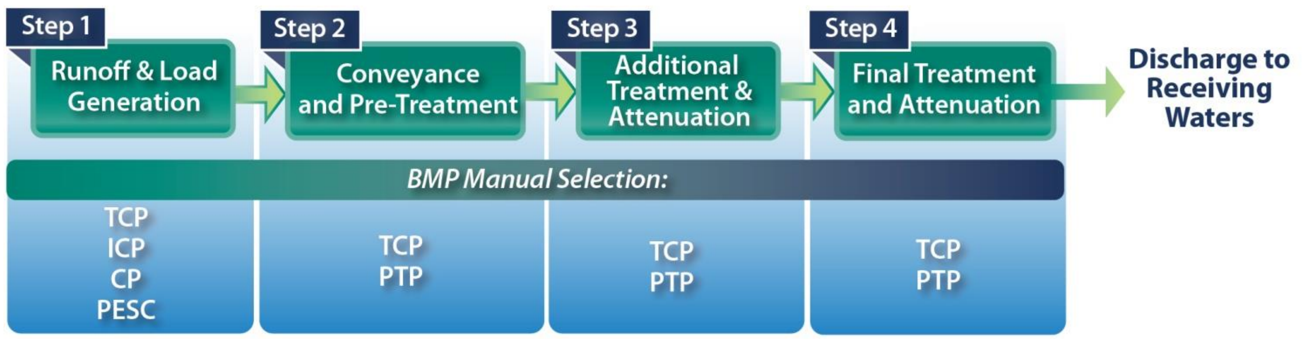


Figure 2 – BMP Selection Process

Temporary BMPs for Construction Activities

Temporary BMPs include many different "good housekeeping" methods as well as short term E&SC activities. The steps involved in utilizing temporary BMPs include design by a Professional Engineer, review and approval by the City of Franklin, implementation, maintenance and inspection. The construction site operator and licensed professional engineer should be responsible for the design and implementation of these BMPs. The contractor bears the responsibility for constructing, maintaining, implementing, and seeking help when it is apparent that the BMPs are not meeting their objectives.

2.2.1 Construction Management Practices

Contractor activities can result in stormwater runoff pollution if not properly managed. The appropriate BMPs shall be utilized to minimize the potential for stormwater pollution. It is recognized that all BMPs are not effective on every construction site. It is important that all BMPs are considered, and that those which are effective for the project at hand should be selected. Considerations for selecting BMPs for contractor activities include the following:

1. **Consider precipitation events**. BMPs may be different on rainy days vs. dry days, winter vs. summer, etc. For instance, a material storage area may be covered with a tarp during the rainy season, but not in the summer. However, plans should be made for some amount of rain, even if it is not expected to generate a flooding event.
2. **Consider the amount of material used**. Less intensive BMP implementation may be necessary if a minimal amount of pollutant containing material is used. Remember that different materials pollute in different amounts.
3. **Consider the volume of water used**. The larger the volume of water used and wastewater generated, the more likely that pollutants transported by this water will reach the stormwater system or be transported off-site.
4. **Consider the site conditions**. BMPs selected will differ depending on whether the activity is conducted on a slope or flat ground, near a stormwater structure or watercourse, etc. Anticipating problems and conducting activities away from certain sensitive areas will reduce the cost and inconvenience of performing BMPs.
5. **Consider accidents**. Pre-establishing a BMP for each conceivable pollutant discharge may be very costly and significantly disrupt construction. As a rule of thumb, establish controls for common (daily or weekly) activities and be prepared to respond quickly to accidents.
6. **Define the difference**. Not everything can or will be deemed an accident and may be classified as negligent disregard of proper practices.

Keep in mind that the BMPs for contractor activities are suggested practices that may or may not apply in every case. Construction personnel should be instructed to develop additional or alternative BMPs that are more cost-effective for a particular project. The best BMP is a construction work force aware of the pollution potential of their activities and committed to a clean worksite. BMP Fact Sheets for Construction Management Practices (CPs) are provided in Section 2 of this manual.

2.2.2 Construction Site Runoff Management Practices

BMPs for erosion and sediment control are selected to meet the BMP objectives based on specific site conditions, construction activities, and cost-effectiveness. Different BMPs may be needed at different times during construction since construction activities are constantly changing the site conditions.

E&SC must begin with the initial prevention of erosion. This can be accomplished through soil protection techniques that will prevent the runoff of soil particles. Erosion and sedimentation will most likely occur to some degree due to active construction areas, and BMP s must be selected to address these issues once they have occurred. Sediment Control BMPs allow sedimentation to be removed from flows before these flows exit the construction site. Consequently, the best protection on active construction sites is generally obtained through simultaneous application of both E&SC BMPs. This combination is effective because it prevents most erosion before it begins and has the ability to capture sediments that become suspended before the transporting flows leave the construction site.

The following general items are provided to aid in preparing the project plans and choosing appropriate E&SC BMPs:

Minimize Disturbed Areas - Project layout and schedule should be compared with on-site management measures that can limit the exposure of the project site to erosion and sedimentation. The City of Franklin Municipal Code sets standards that require responsible construction practices. The following BMPs should be considered in order to reach the desired goals:

1. Do not disturb any portion of the site unless an improvement is to be constructed there immediately.
2. Staging and timing of construction, grading, clearing, etc. can minimize the size of exposed areas and the length of time the areas are exposed and subject to erosion. For example, only areas that are actively involved in cut and fill operations or are otherwise being graded should be exposed.
3. Retain existing vegetation and ground cover where feasible, especially along watercourses and along the downstream perimeter of the site.
4. Construction should be completed as quickly as possible.
5. Landscaping or other stabilization techniques should be installed immediately after the land has been graded to its final contour.
6. Denuded areas should be kept to a minimum during the wet months of December through May.

Stabilize Disturbed Areas – Stabilization is very important because it protects the soil from being eroded away. Stabilization techniques may include vegetative, chemical, or physical soil coverings. It is important to keep in mind that any soil which is exposed is subject to erosion due to a rainfall event, runoff flowing over the soil, wind blowing across that soil, and vehicles driving on the soil. Consequently, it is important that all soil is covered, other than that which is undergoing active construction. Locations on a construction site that are more susceptible to erosion are:

1. Slopes
2. Highly erosive soils
3. Construction entrances
4. Water resource channels
5. Soil stockpiles

Site Perimeter – BMPs for regulating flow in and out of the site perimeter should be a priority. The following ideas should be considered:

1. Disturbed areas or slopes that drain toward adjacent properties, storm drain inlets or receiving waters, should be protected with temporary linear barriers (continuous berms, silt fences, sand bags, etc.) to reduce or prevent sediment discharge while construction in the area is active. In addition, the contractor should be prepared to stabilize those soils with EP measures prior to the onset of rain.

2. When grading has been completed, the areas should be protected with EP controls such as mulching, seeding, planting, or emulsifiers. The combination of EP measures and SC measures should remain in place until the area is permanently stabilized.
3. Significant offsite flows (especially concentrated flows) that drain onto disturbed areas or slopes should be controlled through use of continuous berms, earth dikes, drainage swales, and lined ditches that will allow for controlled passage or containment of flows.
4. Concentrated flows that are discharged off of the site should be controlled through outlet protection, velocity dissipation devices, and level spreaders in order to prevent erosion of downstream areas.
5. Perimeter controls should be placed everywhere runoff enters or leaves the site. They are usually installed just before clearing, grubbing, and rough grading begin. Additional controls within the interior of the construction site should supplement perimeter controls once rough grading is complete.

Internal Swales and Ditches – Until permanent facilities have been constructed, flows are directed toward internal swales, curbs, and ditches. Design and implementation criteria should include the following:

1. Temporary stormwater facilities are susceptible to erosion from concentrated flows, and should be stabilized through temporary check dams, geotextile mats, and under extreme erosive conditions by lining with concrete.
2. Long or steep slopes should be terraced at regular intervals in order to slow the runoff, and to allow for small amounts of sediment to settle out.
3. Slope benches may be constructed with either ditches along them or back-sloped at a gentle angle toward the hill. These benches and ditches intercept runoff before it can reach an erosive velocity and divert it to a stable outlet.
4. A rough surface such as tall grass can be installed to reduce overland flow velocities.

Internal Erosion - After all erosion and sediment control BMPs have been utilized, excessive sediment should be removed from stormwater both within and along the perimeter of the project site. To prevent erosion temporary barriers or traps should slow the velocity of sediment-laden water. This flow should then enter a pond where soil particles may settle. Appropriate strategies for implementing sedimentation controls include:

- Sediment-laden water should be directed to temporary sediment traps.
- Locate sediment basins and traps at low points below disturbed areas.
- Existing and proposed storm drainage structures should be protected from sediment clogging by implementation of inlet protection for area drains and curb inlets.
- Temporary sediment traps or ponds should be constructed at stormwater outfalls for the site.
- Stormwater detention ponds should be excavated early in the project so that they can serve as sedimentation ponds during construction. Remove accumulated sediment and landscape the ponds when the upstream drainage area is stabilized.
- Temporary sediment barriers such as:

- Silt Fence
- Baffles
- Filter Ring
- Filter Berm
- Tubes and Wattles

Stormwater Inlets and Outfalls – All stormwater inlets, including drop inlets, and pipe inlets, should be protected from sediment intrusion if the area draining to the inlet has been disturbed. This protection may include sand bags, sediment traps, or other similar devices. In addition internal outfalls must be protected to reduce scour from high velocity flows leaving pipes or other drainage facilities.

BMPs for Temporary Construction Site Runoff Management Practices (TCPs) are covered in more detail in Section 3 of this manual.

Permanent Erosion Prevention and Sediment Control BMPs

Permanent BMPs are the final improvements to the configuration of the project. They are designed for long-term management of stormwater pollution after construction activities are complete. Example Permanent BMPs include permanent vegetation, buffer zones, bioengineered stream bank stabilization and channel linings. There is no single BMP that will address all long-term stormwater quality problems. A multi-level strategy is required that incorporates source controls, a series of on-site treatment controls, and community-wide treatment controls. This concept was presented earlier in Figure 2, BMP Selection Process. Permanent BMP selection should be considered in the early planning stages of development.

The BMP Fact Sheets for Permanent Erosion Prevention and Sediment Control (PESC) are provided in Section 4 of this manual.

Permanent Stormwater Quality Treatment Controls

Permanent Stormwater Quality Treatment Controls may include Green Infrastructure Practices (GIPs) such as bioretention, swales, detention ponds, and a variety of other features as well as 80% TSS Treatment Practices such as constructed wetlands, sand filters, and filter strips. Licensed professional engineers are responsible for selection of these management practices. These practices should be included in the early planning stages of development. It is important to consider which treatment controls are most efficient and appropriate for the site. In addition, the long-term maintenance responsibilities should be identified in the plans and specifications to prevent future disputes. Typically, this responsibility is left to either the public or private owner of the property. The contractor and owner are responsible for properly constructing and maintaining the permanent controls.

Permanent Stormwater Quality Treatment Controls are implemented most effectively when they are tied in with the actual project design. They are typically selected during the planning phase, in conjunction with the approval of the tentative plan designed during the design phase of a project. When stormwater controls are considered as part of the design, they are conceptually planned and consequently, more effective. The following should be considered in the design process.

1. Is a detention/retention facility required for flood control? Often, facilities are required to maintain peak runoff at predevelopment levels to reduce downstream conveyance system

damage and other costs associated with flooding. Most permanent BMPs can be incorporated into flood control detention/retention facilities with modest design refinements and limited increase in land area and cost.

2. Planned open spaces that have slopes less than 5% may be merged with stormwater quality/quantity facilities. Such integrated, multi-use areas may achieve several objectives at a modest cost.
3. Infiltration BMPs may serve as groundwater recharge facilities, although soil conditions are critical to their success. Detention/retention areas may be created in landscaped areas of the project, and vegetated swales/filters may be used as roadside/median or parking lot median vegetated areas.

The BMP Fact Sheets for Permanent Stormwater Treatment Controls (PTPs) including GIPs and 80% TSS Treatment Practices are provided in Section 5 of this manual.

2.2.3 Effectiveness of Green Infrastructure Practices

GIPs are intended to mimic the natural hydrologic condition and allow stormwater to infiltrate into the ground, evapotranspire into the air, or be captured for reuse. Typical GIPs include: sheet flow, infiltration practices, permeable pavement, bioretention, reforestation, tree box filters, green roofs, and assorted other practices.

These GIPs are designed to meet multiple stormwater management objectives, including reductions in runoff volume, peak flow rate reductions, and water quality protection. Multiple small, localized controls may be combined into a treatment train to provide comprehensive stormwater management. The GIPs listed in this section have been designed to be integrated into many common urban land uses on both public and private property, and may be constructed individually, or as part of larger construction projects. Decentralized management strategies are encouraged to be tailored to individual sites; which can eliminate the need for large-scale, capital-intensive centralized controls; and may improve the water quality in Franklin's water resources.

This Manual includes nine of the most common GIPs, shown in summary Table 1 and Table 2. These tables are included to facilitate selection of the most appropriate practices for a given situation. Fact sheets are included in Section 5 for each practice and provide a brief introduction to the practice, details on performance, suitability, limitations, and maintenance requirements. In addition, each practice is assigned a percentage of volume control based on the particular GIP's ability to control volume from smaller storms and from the first flush of larger storms. Not only does reducing runoff volume decrease the amount of stormwater discharged to sewers, channels and streams, but it is also the most effective stormwater pollution control available.

Table 1 – Effectiveness of BMPs in Meeting Stormwater Management Objectives

Practices	Volume	Peak Discharge	Water Quality
Bioretention	●	●	●
Urban Bioretention	◉	◉	●
Permeable Pavement	●	●	◉
Infiltration Trench	●	●	●
Water Quality Swales (Dry)	◉	◉	●
Extended Detention	○	●	○
Downspout Disconnection	◉	◉	◉
Grass Channels	○	○	○
Sheet Flow	●	●	◉
Reforestation	●	●	●
Rain Tanks/Cisterns*	◉	○	○
Green Roofs	◉	●	●

* A single cistern typically provides greater volume reduction than a single rain tank

● High effectiveness ◉ Medium effectiveness ○ Low effectiveness

Rankings are qualitative. "High effectiveness" means that one of the GIP's primary functions is to meet the objective. "Medium effectiveness" means that a GIP can partially meet the objective but should be used in conjunction with other BMPs. "Low effectiveness" means that the GIP's contribution to the objective is a byproduct of its other functions, and another decentralized control should be used if that objective is important.

Table 2 – Green Stormwater Infrastructure Land Use and Land Area Selection Matrix								
Practices	Criteria							
	Land Use							Land Area Required
	Schools	Com.	Indust.	SF Res.	MF Res.	Parks/Open Space	Roads/ Roadside	
Bioretention	●	●		●	●	●	●	◉
Urban Bioretention	◉	●			●	●	●	○
Permeable Pavement	●	●	◉	●	●	●	●	○
Infiltration Trench	●	●		●	●	●	◉	○
Water Quality Swales (Dry)	●	●			●		●	◉
Extended Detention	●	●	●		●		●	○
Downspout Disconnection	●	◉		●	●	●		○
Grass Channels	●	●		●	●	◉	●	◉
Sheet Flow	●	●		●	●	◉	●	◉
Reforestation	◉		◉	◉	◉	●	●	○/●
Rain Tanks/Cisterns	●	◉	◉	●	●			○
Green Roofs	●	●	●		●			○

● - Well suited for land use applications or high relative dedicated land area required.
◉ - Average suitability for land use applications or moderate relative dedicated land area required.
○ - Low relative dedicated land area required.
Blank – Not applicable for land use.

2.3 Integrated Site Design

The City of Franklin has established a three-part Integrated Site Design (ISD) process in the consideration of stormwater management goals. The ISD process fits well into the general process of land development and serves to assist the designer in making maximum use of the natural features of the site to treat and handle stormwater runoff in a way that integrates such practices into the site layout. Best Management Practice layout planning is accomplished through the ISD process and includes impact reducing site design, integrated stormwater sizing criteria and operations and maintenance of permanent stormwater practices.

Impact-Reducing Site Planning and Design Principles

The first step in the ISD process is to utilize impact-reducing site design principles for stormwater management. Impact-reducing site design includes a number of site design techniques such as preserving natural features and resources, effectively laying out the site elements to reduce impact to the watershed, reducing the amount of impervious surfaces, and utilizing natural features on the site for stormwater management. The goal is to minimize impacts of development by reducing the amount of runoff and pollutants that are generated from a development or redevelopment site, and provide for some nonstructural on-site treatment and control of runoff. Impact-reducing site design concepts can be viewed as both water quantity and water quality management tools that can reduce the size and cost of required structural stormwater controls — sometimes eliminating the need for them entirely — while maintaining or even increasing the value of the property. This site design approach can result in a more natural and cost-effective stormwater management system that better mimics the natural hydrologic conditions of the site, has a lower maintenance burden and increases sustainability.

Step 1: Identify and Delineate Natural Features and Resources

The first step in the impact-reducing site design process is to identify and delineate the natural features and resources that can be used in the protection of water resources by reducing stormwater runoff, providing runoff storage, reducing flooding, preventing soil erosion, promoting infiltration, and removing stormwater pollutants. The design engineer should collect and review information on the existing site conditions and delineate existing site features such as:

- Areas of undisturbed vegetation
- Floodplains and riparian areas
- Ridgetops and steep slopes
- Natural drainage pathways
- Water resource channels and streams
- Aquifers and recharge areas
- Wetlands
- Soil types
- Other natural features or critical areas
- Other features that should be identified in this step are adjacent areas, existing developed areas, and existing stormwater facilities and infrastructure.

Step 2: Conserve Natural Features and Resources

The conservation of natural features such as floodplains, soils, and vegetation helps to retain predevelopment hydrology functions, thus reducing runoff volumes. Impacts to natural features should be minimized by reducing the extent of construction and development practices that adversely impact predevelopment hydrology functions. This includes:

- Building upon the least porous soils or limiting construction activities to previously disturbed soils
- Avoiding mass clearing and grading, and limiting the clearing and grading of land to the minimum needed to construct the development and associated infrastructure
- Avoiding disturbance of vegetation and soil on slopes and near surface waters
- Leaving undisturbed riparian buffers along both sides of the water resource, as defined in the City of Franklin Municipal Code
- Preserving sensitive environmental areas, historically undisturbed vegetation, and native trees
- Conforming to watershed, conservation, and open space plans
- Designing development to fit the site terrain, and building roadways parallel to contour lines wherever possible
- Clustering development to preserve porous soils, natural streams, natural channels and natural slopes
- Avoid floodplains

Step 3: Manage Stormwater Close to the Source

Redirecting runoff back into the ground, close to the point of origin, provides both environmental and economic benefits. Traditional stormwater systems, which collect and convey stormwater, generally increase flows and are likely to suffer failures over time. Techniques include:

- Use GIPs to infiltrate stormwater into the ground instead of concentrating the flow and routing it offsite
- Disconnect impervious surfaces wherever feasible

Step 4: Design to Reduce Runoff Impacts

After conservation areas have been delineated, there are additional opportunities in the preliminary stages of a site design for avoiding downstream stormwater impacts from the development. These primarily deal with the location and configuration of lots or structures on the site and include the following recommendations and options:

- Fit the design to the terrain
- Reduce the limits of clearing and grading (i.e., limit clearing and grading areas to what is absolutely necessary)
- Locate development in less sensitive areas (e.g., outside of wetlands)

- Utilize open space
- Use nontraditional lot designs for residential areas (think outside the box)
- Consider creative development design
- Preserve riparian buffers and undisturbed areas
- Use natural drainage paths instead of storm sewer infrastructure
- Use vegetated swales instead of curb and gutter
- Drain runoff to pervious areas

Step 5: Reduce and Disconnect Impervious Cover

Reducing and disconnecting impervious surfaces increases the rainfall that infiltrates into the ground. Impervious areas should be reduced by maximizing landscaping and using pervious pavements. In addition, the amount of impervious areas hydraulically connected to impervious conveyances (e.g., driveways, walkways, culverts, streets, or storm drains) should be reduced as much as possible. Examples include:

- Installing green roofs
- Directing roof downspouts to vegetated areas, bioretention,, or planter boxes, and routing runoff into vegetated swales instead of gutters
- Using porous pavements where permitted
- Installing shared driveways that connect two or more homes or installing residential driveways with center vegetated strips
- Allowing for shared parking in commercial areas
- Encouraging building developers to increase their number of floors instead of their building's footprint

Step 6: Minimize Soil Compaction

Soil compaction disturbs native soil structure, reduces infiltration rates, and limits root growth and plant survivability. When protected, local soils can have a significant infiltration capacity, and can help meet design requirements. While soil compaction is necessary to provide structurally sound foundations, areas away from foundations are often excessively compacted by vehicle and foot traffic during construction. Minimizing soil compaction can be achieved by:

- Reducing disturbance through design and construction practices
- Limiting areas of access for heavy equipment
- Avoiding extensive and unnecessary clearing and stockpiling of topsoil
- Maintaining existing topsoil and/or using quality topsoil during construction

Integrated Stormwater Sizing Criteria

The second step in the ISD process is to utilize an integrated sizing approach for meeting the City's stormwater runoff **quantity** and **quality** management requirements. These criteria allow the site engineer to calculate the stormwater control volumes required for water quality and flood protection. The purpose is to provide a framework for designing (sizing) a stormwater management system to:

- Reduce the volume of stormwater runoff and remove runoff pollutants to improve water quality;
- Reduce downstream overbank flooding; and
- Safely pass or reduce the runoff from extreme storm events.

The Integrated Stormwater Sizing Criteria is an integrated set of criteria or design standards that allow the site engineer to size and design structural stormwater controls to address the above objectives. The criteria are summarized in Table 3.

Table 3 - Summary of Sizing Criteria for Stormwater Control and Mitigation

Sizing Criteria		Description
Water Quantity	**Water Quality**	Infiltrate, evapotranspire, harvest and/or use, at a minimum, the first inch of every rainfall event preceded by 72 hours of no measurable precipitation. For projects that cannot meet 100% of the runoff reduction requirement, the remainder of the stipulated amount of rainfall must be treated prior to discharge with a technology expected to remove 80% total suspended solids (TSS).
	Overbank Flood Protection	Provide peak discharge control of the 2, 10, 25, and 50-year storm event on the stormwater management system, adjacent property, and downstream facilities and property to reduce overbank flooding through detention.
	Extreme Flood Protection	Evaluate the effects of the 100-year storm on the stormwater management system, adjacent property, and downstream facilities and property. Manage the impacts of the extreme storm event through detention controls and/or floodplain management.

Each of the integrated stormwater sizing criteria are intended to be used with one another to address the overall stormwater impacts from a development site. When used as a comprehensive set, the integrated criteria control the entire range of hydrologic events, from the smallest runoff-producing rainfalls to the 100-year storm. Figure 3 graphically illustrates the relative volume requirements of each of the integrated stormwater sizing criteria and demonstrates that the criteria are generally "nested" within one another, (i.e., the extreme flood protection volume requirement also contains the overbank flood protection volume and the water quality treatment volume). This nesting provides efficiency when constructing and maintaining stormwater controls.

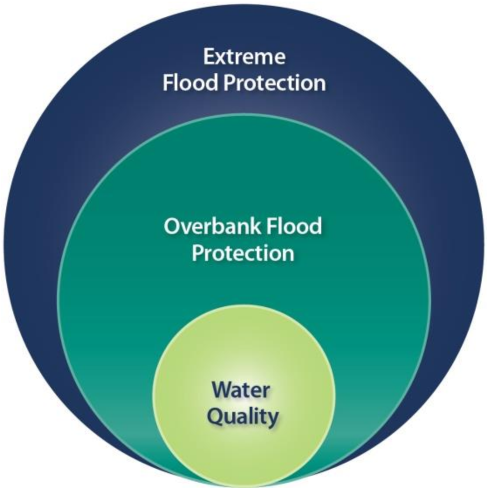


Figure 3 – Representation of the Integrated Stormwater Sizing Criteria

The integrated stormwater sizing criteria is described in more detail below.

2.3.1 Water Quality

Hydrologic studies show that small-sized, frequently occurring storms account for the majority of rainfall events that generate stormwater runoff. Consequently, the runoff from these storms also accounts for a large portion of the annual pollutant loadings. Therefore, by treating these frequently occurring smaller rainfall events and a portion of the stormwater runoff from larger events, it is possible to effectively mitigate the water quality impacts from a developed area whether located in the headwater reaches of the watershed or close in proximity to a 4^{th} order stream.

The Runoff Reduction Method (RRM), presented in Chapter 3, can achieve both volume control and pollutant removal stormwater management goals. For projects that cannot meet 100% of the runoff reduction requirement, the remainder of the stipulated amount of rainfall must be treated prior to discharge with a technology expected to remove 80% TSS in order to comply with the City's NPDES Phase II MS4 Permit. This combined approach allows the designer to apply RRM design principles along with 80% TSS design principles to meet the compliance standard.

Chapter 3.1 of this manual provides technical details regarding RRM. Chapter 3.2 provides technical details regarding the RRM and 80% TSS fall back combined methodology.

The City of Franklin reserves the right to require other treatment goals for other pollutants of concern based on other regulatory requirements or needs (e.g. Total Maximum Daily Load studies).

2.3.2 Overbank Flood Protection (Qp)

An increase in impervious areas by development increases the potential for downstream flooding. The purpose of overbank flood protection is to prevent an increase in the frequency and magnitude of damaging out-of-bank flooding (i.e. flow events that exceed the capacity of the channel and enter the floodplain). It is intended to protect downstream properties from flooding at middle-frequency storm events. The Overbank Flood Protection criterion specifies that the post-development 2, 10, 25, and 50-year, 24-hour storm peak discharge rate (denoted Qp) not exceed the pre- development (or undisturbed natural conditions) discharge rate.

2.3.3 Extreme Flood Protection (Qf)

The intent of the extreme flood protection is to prevent flood damage from infrequent but large storm events, maintain the boundaries of the mapped 100-year floodplain, and protect the physical integrity of the structural stormwater controls as well as downstream stormwater and flood control facilities. The Extreme Flood Protection criterion specifies that all stormwater management facilities be designed to control runoff for the 100-year, 24 hour storm (denoted Qf) so that the rate at which flow is released over the entire runoff discharge period is equal to or less than predevelopment flows.

Operations and Maintenance

The third and final step in the ISD process is to provide for operation and maintenance (O&M) oversight of the water quality and quantity BMPs. Without proper care and maintenance, the BMPs ability to perform its design function is reduced and it is no longer in compliance with City regulations.

A Stormwater Management Facilities O&M Agreement is required to be submitted with all Stormwater Permit Applications. If final configuration of the stormwater system changes from the design, the O&M Agreement must be updated to reflect changes. As part of the O&M Agreement, a Long Term BMP Maintenance Plan must be developed by the design professional engineer (Found in Section 5). This plan includes a description of the stormwater system, the required inspections, the inspection schedule, and how the inspections should be documented. A report must be submitted to the City of Franklin by July 1 of each year that includes documentation of the inspection and maintenance activities performed.

Additional O&M guidance for Green Infrastructure controls and TSS Practices can be found within each design specification located in Section 5.

3 Post Construction Water Quality

3.1 The Runoff Reduction Method

Introduction

3.1.1 Background

The Runoff Reduction Method (RRM) will serve as the basis for Franklin's approach to Green Infrastructure (GI) requirements in the NPDES Phase II MS4 Permit. The basic RRM derivation can be found in original References 11 and 12. The RRM has been slightly modified and localized for the middle Tennessee region.

In the past, Franklin's pollution reduction approach focused mainly on engineered controls to reduce stormwater pollution as runoff flowed through structural controls, and required that they meet an 80% or more removal efficiency of total suspended solids. Open space land use was of only minor importance. Under the RRM, every land surface will now have an assigned rating in terms of volume of rainfall capture. For example, if open space can infiltrate a significant rainfall event, and it can be credited with 100% TSS removal for all the volume it infiltrates, then the open space itself becomes an effective control. Even impervious surfaces capture a small amount of water and therefore do not generate 100% runoff.

Volume removal is the focus of this approach; and volume reduction equals pollution reduction. Thus, understanding and calculating every aspect of a site's land condition in relation to volume removal is important.

3.1.2 Objectives

The basis for the RRM is a rainfall volume capture goal. The City of Franklin's site design standards require, in combination or alone, management measures that are designed, installed and maintained to infiltrate, evapotranspire, harvest and/or use, on average, the first inch of every rainfall event preceded by 72 hours of no measurable precipitation. The RRM was designed to fulfill several complimentary objectives:

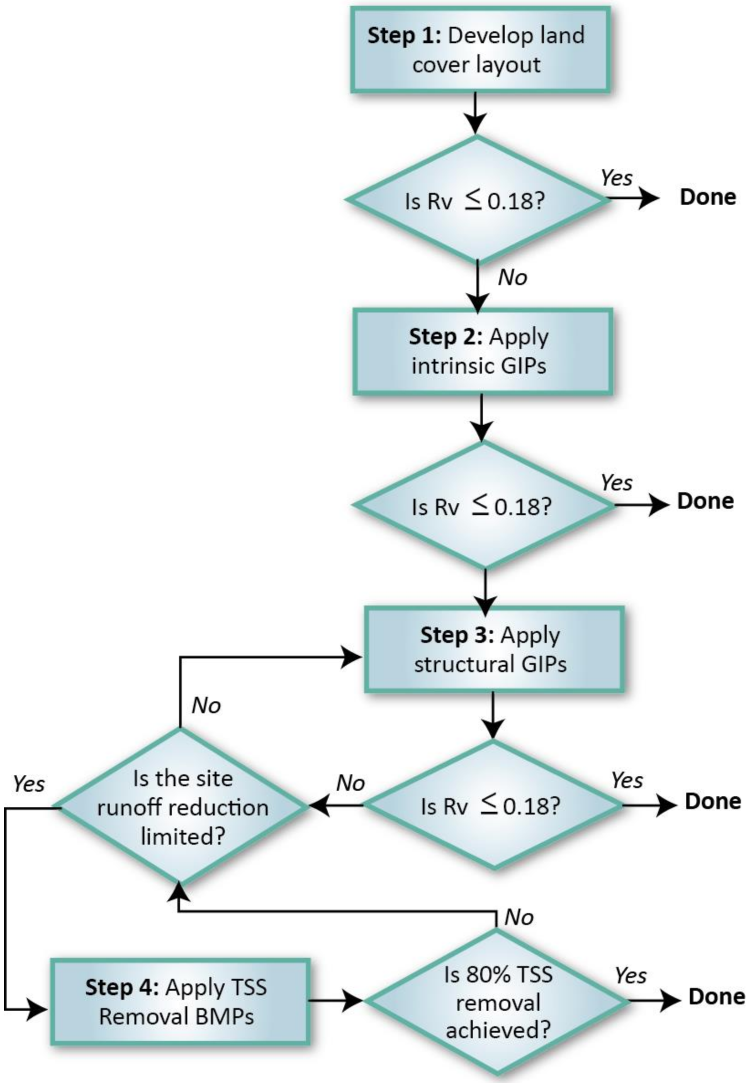
- Meet the one-inch capture requirement under the NPDES MS4 Permit;
- Reflect local hydrologic and land conditions;
- Encourage and incentivize the use of natural solutions; and
- Provide an approach that is simple and effective for a range of development projects

It was found that these objectives could largely be met through the use of a single overarching design standard, backed by specific volume-capture standards for structural controls and rainfall intensity scaled runoff coefficients for other land uses. To be eligible for approval of a site design under this approach the designer must lay out the site such that the total rainfall for a one-inch event of moderate intensity is captured and treated on site through a combination of infiltration, evapotranspiration, harvest and/or use. This objective is accomplished through site layout and GIP design.

The first step in determining if the standard is met is to determine the volumetric runoff coefficient, Rv, which is the percentage of fallen precipitation that runs off of a specific land use area (See Equation 1). Rv within this method reflects a site's post-development runoff volume for storms in the one-inch or larger range. Based on national studies and standards, and supported by local rainfall-runoff analysis for middle Tennessee soils, it was found that an Rv value of 0.18 generally indicates the capture of the first one-inch of rainfall. Storms larger than one inch may cause runoff.

Each land use is assigned an Rv value. Once Rv values have been developed, they must be weighted for the respective areas. If the weighted Rv for the whole site is 0.18 or less, then the standard has been met. If the Rv standard has not been met, GIPs consisting of intrinsic designs and structural controls devised to capture the remaining required volume are added to the design. These effectively modify the Rv value for contributing drainage areas to that intrinsic design or control. These are shown in Tables 4 and 5.

In summary, in meeting this standard the designer will have carefully considered the effective use of: (1) land cover that reduces runoff; (2) more intrinsic site design GIPs that further reduce runoff; and (3) structural GIPs that capture the remaining volume required to meet the compliance standard. In each step the Rv values and supporting design specifications have been carefully crafted to effectively meet compliance standards while retaining focus on natural approaches. In every case values have been localized through the balanced use of the most recent data sources and continuous simulation modeling of local conditions.



3.1.3 Conceptual Steps in the Runoff Reduction Method

The RRM follows the steps shown below:

Step 1: Reduce Runoff Through Land Use and Ground Cover Decisions

This step focuses on the "background" land cover and how much rainfall it removes from runoff. Design activities in Step 1 focus on impervious area minimization, reduced soil disturbance, forest preservation, etc. The goal is to minimize impervious cover and mass site grading and to maximize the retention of forest and vegetative cover, natural areas and undisturbed soils, especially those most conducive to landscape-scale infiltration.

Calculations for the RRM Step 1 include the computation of volumetric runoff coefficients (Rv) for land use and Hydrologic Soil Group (HSG) combinations (including impervious cover). Site cover runoff coefficients are shown in Table 4.

Step 2: Apply Environmental Site Design Practices (Non-Structural GIPs)

If the target volume capture (Rv ≤ 0.18) has not been attained in Step 1 then Step 2 is required. This step focuses on implementing the more intrinsic GIPs during the early phases of site layout. In this step the designer enhances the ability of the background land cover to reduce runoff volume through the planned and engineered use of such practices as sheet flow, and planned reforestation. Each of these practices is assigned an ability to reduce one-inch of rainfall in a storm of moderate intensity; and this assignment is captured in the Runoff Removal Credit or the RR Credit. RR Credit values for non-structural GIPs are shown in Table 5.

Step 3: Apply Structural GIPs

If the target one-inch capture volume (Rv ≤ 0.18) has not been attained, Step 3 is required. In this step, the designer experiments with combinations of more structural GIPs on the site. In each case, the designer estimates the area to be treated by each GIP to incrementally meet the overall runoff reduction goal. Such engineered practices as infiltration trenches, bioretention, green roofs, permeable pavement, etc. are envisioned. Design and sizing standards have been created for each of these GIPs to insure their ability to meet the one-inch volume capture still required after Steps 1 and 2 have been implemented. RR Credit values for structural GIPs are also shown in Table 5.

The guidance for the effectiveness of the various GIPs is expressed in terms of percent volume reduction (Runoff Reduction Credit). At the end of Step 3, the designer must have achieved the required one-inch volume capture – accomplished by attaining an area weighted Rv value of 0.18 or less.

However, if the Runoff Reduction Performance Standard has not been achieved after Step 3 and the development is determined to be runoff reduction limited (i.e., runoff reduction practices cannot be implemented at the site sufficiently to meet the Runoff Reduction Performance Standard), then the site designer must request approval to use TSS Removal Best Management Practices (BMPs) and, if approved, proceeds to Step 4.

Step 4: Apply TSS Removal BMPs

The application of TSS Removal BMPs will occur only if the Runoff Reduction Performance Standard has not been achieved in Steps 1 through 3, and the site is approved for TSS Removal BMPs because it is runoff reduction limited. In this step, the designer will capture the remainder of the required 1-inch rainfall that was not captured in the Runoff Reduction Method design (in steps 1 through 3), and will treat this volume to the Pollutant Removal Performance Standard of 80% TSS Removal. TSS Removal BMPs such as stormwater wetlands, sand filters, and wet ponds can be used for this purpose.

Technical Details

3.1.4 Step 1: Land use Rv Values

The volumetric runoff coefficient (Rv) is the ratio of the runoff divided by the target rainfall. The Rv values refer to the ratio of rainfall that falls on and is discharged from each drainage area. If 45% of the rainfall for storms in the one-inch range and larger is discharged from the site, the Rv value equals 0.45. Unlike a Rational Method C Factor, for example, Rv is not a constant individual storm-based value, but is rainfall intensity and total depth dependent. Rv values could be developed for individual storms, seasons, or even on an annual basis. Table 4 shows the Rv values that are applicable for the City of Franklin in order to estimate runoff from larger storms of moderate intensity meeting the one-inch and greater standard.

Table 4 - Site Cover Runoff Coefficients

Soil Condition	Volumetric Runoff Coefficient (R_V)			
IMPERVIOUS COVER	0.95			
HYDROLOGIC SOIL GROUP	**A**	**B**	**C**	**D**
FOREST COVER	0.02	0.03	0.04	0.05
TURF	0.15	0.18	0.20	0.23

These values serve as the basis for Step 1 in application of the RRM. The development of an area-weighted estimate of the total site Rv value using site land uses is shown below in Equation 1. Example 1 on the following page demonstrates Step 1 using Equation 1

$$\text{Weighted Rv} = \frac{[(\text{Rv}_1 \times \text{A}_1) + (\text{Rv}_2 \times \text{A}_2) + \cdots]}{(\text{A}_1 + \text{A}_2 + \cdots)} \qquad \textbf{Equation 1}$$

EXAMPLE 1 STEP 1

The first step is to layout the project site and divide it into sub-areas of a specific land use type and Rv. As shown in Figure 4 below, if we have a 10 acre site and 50% of the site was impervious, 20% forest, and 30% turf grass all over HSG B Soils the Rv value would be:

$$\text{Weighted Rv} = \frac{[(\text{Rv}_1 \times \text{A}_1) + (\text{Rv}_2 \times \text{A}_2) + (\text{Rv}_3 \times \text{A}_3)]}{(\text{A}_1 + \text{A}_2 + \text{A}_3)}$$

$$\text{Weighted Rv} = \frac{[(0.95 \times 5.0\text{ac}) + (0.03 \times 2.0\text{ac}) + (0.18 \times 3.0\text{ac})]}{(5.0\text{ac} + 2.0\text{ac} + 3.0\text{ac})}$$

$$\text{Weighted Rv} = 0.54$$

That is, 54% of the rainfall for storms in the range of one-inch and greater runs off. This step does not consider the flow path of the runoff but simply the land use. The requirement is the capture of the first inch of rainfall and an Rv of 0.18 or less. Additional GIPs must be planned and implemented to meet the required Rv for the site.

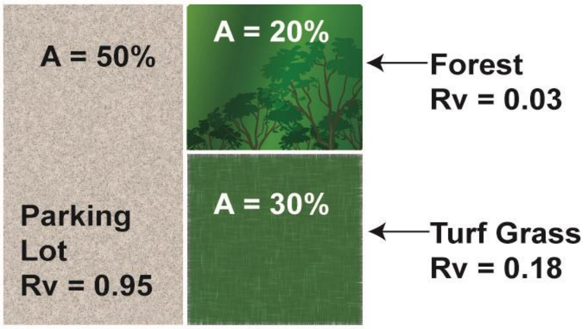


Figure 4 – Site Example with Land Uses

3.1.5 Steps 2 and 3: Green Infrastructure Practice Rv Values

Steps 2 and 3 of the RRM involve the planning and design of Green Infrastructure Practices (both intrinsic Step 2 and structural Step 3) to reduce runoff from sub-areas in Step 1. Each sub-area's Rv may be reduced by allowing runoff to flow into downstream GIPs. After GIPs are implemented the total site Rv is recalculated using the GIP modified Rv for each sub-area. In order to satisfy the City's requirement the site Rv must be 0.18 or less. Table 5 lists acceptable GIPs and the assigned Runoff Reduction Credits (RR Credit) for each. These RR Credit values correspond with the values listed in each GIP's specification. Several GIP's in Table 5 have two levels of design options, the two levels refer to specific design requirements contained in the specification sheets within Section 5 of this manual.

Table 5 - Green Infrastructure Practices Runoff Reduction Credit Percentages								
Green Infrastructure Practice	% Rainfall Volume Removed/Captured – RR Credit							
	Level 1**				Level 2**			
1. Bioretention	60				80			
2. Urban Bioretention	60				N/A			
3. Permeable Pavement	45				75			
4. Infiltration Trench	50				90			
5. Water Quality Swale	40				60			
6. Extended Detention	15				N/A			
7. Sheet Flow *	50				75			
8. Reforestation (A, B, C, D soils)	96	94	92	90	98	97	96	95
9. Green Roof	80				90			

*See GIP for additional RR Credits.

**See GIP for additional information of the distinction between Level 1 and Level 2 design.

Note that the first six GIPs themselves occupy site land area. Because of their ability to absorb the rain that falls on them they are assigned the corresponding Forest Cover Rv values by soil type from Table 6.

Table 6 - Green Infrastructure Practice Cover Coefficients				
Green Infrastructure Practice	Forest Cover Rv Values for GIPs by Hydrologic Soil Group			
	A	B	C	D
Bioretention Urban Bioretention Permeable Pavement Infiltration Trench Water Quality Swale Extended Detention	0.02	0.03	0.04	0.05

To calculate the Modified Rv value for a sub-area flowing through a GIP, use Equation 2 shown below.

$$\text{Modified Sub-area Rv} = (\text{Sub-area Rv})(1 - \text{RR Credit}) \qquad \textbf{Equation 2}$$

The Modified Sub-area Rv equals the Sub-area Rv as treated by a GIP. Example 1 is continued below and demonstrates Steps 2 and 3 using Equation 2 above.

EXAMPLE 1 - STEP 2 & 3

In Step 2 and 3, the designer uses intrinsic and structural GIPs to reduce the weighted Rv. Continuing with Example 1 Step 1 and using Figure 4, the impervious area has an Rv value of 0.95, half of the parking area can be discharged through one intrinsic GIP, sheet flow level 2 over turf (Table 5: 75% RR Credit for HSG B soil). The other half of the parking area can be discharged through one structural GIP, bioretention with level 2 design (Table 5: 80% RR Credit). The following modified Rv would result using Equation 2: (Note that the forest and turf do not drain to the bioretention area)

$$\text{Sheet Flow (Level 2) Modified Sub-area Rv} = 0.95 *(1-0.75) = 0.24$$

$$\text{Bioretention Modified Sub-area Rv} = 0.95 *(1-0.80) = 0.19$$

Thus, the intrinsic GIP, sheet flow level 2 via a level spreader reduces half the impervious area's Rv from 0.95 to **0.24** and the bioretention facility meeting the level 2 design criteria would cause the remainder of the impervious area's Rv to be reduced from 0.95 to **0.19**. Additionally, the bioretention area occupies land area and can be given a Forest Cover on HSG B soil Rv.

Recalculating the weighted Rv using Equation 1 results in the following:

$$\text{Weighted Rv} = \frac{[(\mathbf{0.24} \times 2.5\text{ac}) + (\mathbf{0.19} \times 2.5\text{ac}) + (\mathbf{0.03} \times 0.14ac) + (0.03 \times 2.0\text{ac}) + (0.18 \times 2.86\text{ac})]}{(10\text{ac})}$$

$$\text{Weighted Rv} = 0.17$$

Using sheet flow via a level spreader over HSG B soil and a bioretention area meeting the Level 2 design criteria runoff from the impervious area is treated and the weighted Rv is reduced to just below the requirement of 0.18.

3.1.6 Rv Calculations for GIPs in Series

The calculation of volume removal rate for controls in series can be complex and specific GIP dependent. The upstream control has the benefit of initially handling runoff from the many small storms while the second GIP in series must handle the overflow from the first – a set of fewer and larger storms. Therefore, the ability to capture instantaneous volumes and store them for later removal is key for the downstream controls. Only the first six controls in Table 5 can be used as the downstream GIP in series: bioretention, urban bioretention, permeable pavement, infiltration trench, water quality swale, and extended detention.

The following equation shall be used for calculation of the Modified Subarea Rv for GIPs in series:

$$\text{Modified Sub-area Rv}_{\text{SERIES}} = \text{Sub-area Rv}(1 - RR_1 \text{ Credit})(1-RR_2 \text{ Credit}) \qquad \textbf{Equation 3}$$

Where Subarea Rv is the area weighted Rv of the land cover flowing into the first GIP in the series (e.g. Subarea Rv = 0.95 for 100% impervious area, *or* if 50% of the area was impervious and 50% of the area was turf on HSG B soil then the Sub-area Rv is 0.57). RR_1 Credit is the percent volume reduction credit for the first GIP in the series from Table 5 and RR_2 Credit is the percent volume reduction credit for the second

GIP in the series from Table 5. Credit will be granted for no more than two structural controls used in series.

EXAMPLE 2 - GIPs in Series

This example demonstrates how to treat an impervious area by two structural GIPs in series. A 5.0 acre site is 80% impervious (4 ac), 0.75 acre is turf grass, and 0.25 ac is forested. The underlying soils are all HSG C. The impervious area is discharged to two water quality swales level 2 (Table 5: 60% RR Credit) into two bioretention areas level 1 (Table 5: 60% RR Credit). Calculate the Rv for each of the three sub areas of the site – only the impervious area is demonstrating GIPs in series:

(1) Impervious area is discharged through water quality swales and bioretention areas
Modified Sub-area Rv_{SERIES} = 0.95*(1-0.60)(1-0.60) = 0.15

(2) Turf grass HSG C Rv = 0.20

(3) Forest in C Soil Rv = 0.04

Weighted Rv for criteria attainment using Equation 1 is:

$$\text{Weighted Rv} = \frac{[(\mathbf{0.15} \times 4\ \text{ac}) + (\mathbf{0.20} \times 0.75\ \text{ac}) + (\mathbf{0.04} \times 0.25\ ac)]}{(5\ \text{ac})}$$

$$\text{Weighted Rv} = 0.15$$

This equation says that 95% of the rainfall runs off the impervious area and enters the water quality swales of which 60% of is held in the designed swale. The remainder of the prescribed volume would enter the bioretention facility (the largest storms) and 60% of which is captured designed as a level 1 facility allowing approximately 15% to runoff the site in the design situation on an average annual basis.

EXAMPLE 3 - GIPs in Series

A 2.0 acre site is 75% impervious (2 ac), and 0.5 acre is turf grass. The underlying soils are all HSG B. The impervious area consists of a parking lot and building. The building is 0.5 acres and is discharged to a Level 2 Bioretention (Table 5: 80% RR Credit). The parking lot is 1.0 acre and contains 0.5 acre of level 1 pervious pavers (Table 5: 45% RR Credit), the remainder of the runoff not credited by the pavers is captured by a level 2 bioretention (Table 5: 80% RR Credit). Calculate the Rv for each of the two sub areas of the site – only the impervious area from the parking lot is demonstrating GIPs in series:

(1) Parking lot impervious area is discharged and captured by pervious pavers and then by level 2 bioretention

$$\text{Modified Sub-area } Rv_{SERIES} = 0.95*(1-0.45)(1-0.80) = 0.11$$

(2) Building is discharged to a Level 2 Bioretention

$$\text{Modified Sub-area } Rv = 0.95*(1-0.80) = 0.19$$

(3) Turf grass HSG B Rv = 0.18

Weighted Rv for criteria attainment using Equation 1 is:

$$\text{Weighted Rv} = \frac{[(\mathbf{0.11} \times 1\text{ ac}) + (\mathbf{0.19} \times 0.5\text{ ac}) + (\mathbf{0.18} \times 0.5\ ac)]}{(2\text{ ac})}$$

$$\text{Weighted Rv} = 0.15$$

This equation says that 95% of the rainfall runs off the parking lot impervious area enters the pervious pavers and bioretention of which 45% is held in the pavers and 80% of the remainder is held in the bioretention practice. The runoff from the building impervious is captured by the bioretention and when the turf grass (HSG B) is taken into account on an average annual basis 15% runs off the site. Thus, this site meets the Rv target of 0.18 Rv or 18% runoff on an average annual basis.

3.1.7 Sizing of Media-Based GIPs

The following guidance is provided for sizing media based GIPs types of facilities. Details for each type of GIP are provided within Section 5 of this manual. All media-based GIPs shall be sized to provide storage volume for the complete runoff from one inch of rain over the contributing drainage area (CDA). Thus all media storage GIPs shall be sized using the following equations:

$$\text{Tv} = \text{Mult.}\left[\text{P(CDA)(Rv)}\left(\frac{43{,}560\text{ ft}^2}{1\text{ ac}}\right)\left(\frac{1\text{ ft}}{12\text{ in}}\right)\right] = \text{n(D)(SA)} \qquad \textbf{Equation 4}$$

where:

Tv	=	GIP treatment volume in cubic feet
Mult.	=	the multiplier for the GIP from Table 7, if applicable

CDA = the contributing drainage area in acres to the GIP.
P = 1 inch
Rv = runoff coefficient for the CDA, if an upstream GIP is used the Rv would be the reduced Modified Sub-area Rv
SA = surface area in square feet of the GIP
D = media depth of GIP in feet
n = Porosity
(D)(n) = D_E if more than one media type is required (Equation 5 below)

Note that the Rv value above is for the total area draining to the control. The Treatment Volume (Tv) must be calculated for the volume of runoff from one inch of rainfall that will be discharged to the GIP from the contributing drainage area. Therefore, when using Equation 4 to calculate Tv for a solitary GIP, RR Credits cannot be applied in the calculation of the weighted Rv. When using the equation to calculate Tv for GIPs in series, the weighted Rv can include consideration of the GIP credit that is provided by the upstream GIP when calculating the Tv for the downstream GIP. The resulting Tv is then applicable to the treatment volume that will be required for the downstream GIP. (This methodology is incorporated into the tool)

Table 7 - Multipliers for GIPs for use in Equation 4		
Green Infrastructure Practice	Multiplier	
	Level 1	Level 2
1. Bioretention	1	1.25
2. Urban Bioretention	1	n/a
3. Permeable Pavement	1	1.1
4. Infiltration Trench	1	1.1
5. Water Quality Swale	1	1.1
6. Extended Detention	1.25	n/a

Table 8 provides basic volume-based specifications for the standard recommended soil-based media and gravel. Soil-based media is used for GIPs: bioretention, water quality swales and urban bioretention. Gravel is used for design alternatives for the above listed GIPs, as well as, the storage layers for permeable pavement and infiltration trenches.

Average porosity of non-compacted soil and gravel is assumed to be 0.40. Field capacity of the soil is the amount of moisture typically held in the soil/gravel after any excess water from rain events has drained and varies greatly between soil-based media and gravel.

Table 8 - Media Volume-Based Specifications		
Parameter	Value	
	Porosity	Field Capacity
Soil-Based Media[1]	0.40	0.25
Gravel[2]	0.40	0.04
Ponding	1.0	NA

1. Soil-Based Media GIPs - bioretention, water quality swales and tree planter boxes
2. Gravel GIPs – design alternatives for GIPs in 1, storage layers for permeable pavement and infiltration trenches

To find the equivalent storage depth for media-based GIPs with multiple layers of media, the equivalent storage depth must be calculated using the following equation:

$$\text{Equivalent Storage Depth} = D_E = n_1(D_1) + n_2(D_2) + \cdots$$ **Equation 5**

Where, n1 and D1 are for the first layer, etc.

EXAMPLE 4 – Treatment Volume Calculation

Using Example 1, the bioretention level 2 treatment volume will need to be calculated to design the practice. The area draining to the bioretention area is completely impervious (2.5 acres) therefore the Rv is 0.95 (note: if the contributing drainage area to the bioretention area was comprised of 50% impervious area and 50% turf HSG B the Rv used in the treatment volume calculation below would be 0.57). The Rv of the contributing drainage area in this example is 0.95.

Rv = 0.95

The bioretention structure is level 2 and thus will have 1.25 multiplier (Table 7) for the treatment volume, a media depth of 36 inches and a maximum of 6 inches of ponding. The Equivalent Depth = (3 ft)(0.4) + (0.5 ft)(1.0) = 1.7 ft. Then by application of Equations 4 and 5, solving for SA:

$$\text{Tv} = 1.25 \times 1\text{in} \times 2.5\text{ac} \times 0.95\left(\frac{43{,}560\ \text{ft}^2}{1\ \text{ac}}\right)\left(\frac{1\ \text{ft}}{12\ \text{in}}\right)$$

$$\text{Tv} = 10{,}777\ \text{ft}^3$$

$$\text{Tv} = \text{n}(\text{D}_\text{E})(\text{SA})$$
$$10{,}777\ \text{ft}^3 = 1.7\ \text{ft}\ (\text{SA})$$
$$\text{SA} = 6{,}339\ \text{ft}^2$$

The design treatment volume that the bioretention area must capture is 10,777 ft^3, the required surface area if the bioretention cell was designed with 36 inches of media and 6 inches of ponding is 6,339 ft^2. The surface area required would significantly decrease if the designer chose to increase the media depth.

3.1.8 Calculation of Curve Numbers with Volume Removed

The removal of volume by GIPs changes the runoff depth entering downstream stormwater quantity structures. An approximate approach to accounting for this in reducing the size of peak flow detention facilities is to calculate an "effective SCS curve number" (CNadj) which is less than the actual curve number (CN). CNadj can then be used in hydrologic calculations and in routing. The method can also be used for other hydrologic methods in which a reduction in runoff volume is possible.

Equation 6 provides a way to calculate a total runoff if the rainfall and curve number are known.

$$\text{Q} = \frac{(\text{P}-0.2\times\text{S})^2}{(\text{P}+0.8\times\text{S})} \quad \text{and} \quad \text{S} = \frac{1000}{\text{CN}} - 10$$ **Equation 6**

Equation 6 is the standard SCS rainfall-runoff equation where P is the inches of rainfall for the 24-hour design storm (Table 9), and Q is the total runoff in depth for that storm in inches.

Table 9 - Franklin 24-Hour Rainfall Depths	
Return Period (Years)	**Rainfall Depth (Inches)**
2	3.68
5	4.48
10	5.12
25	6.02
50	6.75
100	7.51

The adjusted total runoff in depth entering the flood control facility downstream of a GIP is calculated by taking the difference in the original total runoff in depth and the depth captured by the GIP (Tv from Equation 4) expressed in watershed inches using Equation 7 where CDA is the drainage area in acres for the subarea in question.

$$Q_{adj} = Q - \frac{12 * Tv}{43{,}560 * CDA}$$

Equation 7

Equation 8 provides a method to calculate the modified curve number once the Qadj is found.

$$CN_{adj} = \frac{1000}{10 + 5P + 10Q_{adj} - 10\left(Q_{adj}^{2} + 1.25Q_{adj}P\right)^{1/2}}$$

Equation 8

The steps in calculating an adjusted Curve Number (CNadj) are:

Step 1. Calculate Total Runoff for Storm (Q)

Choose the design return period, and using that rainfall as P, calculate an initial Q using Equation 6 and the calculated site curve number.

Step 2. Calculate GIP Capture Volume (Tv)

Compute the captured volume in the GIP control using Equation 4 or proven cistern volume assuming a 72 hour inter-event dry period since the last cistern filling event.

Step 3. Calculate Adjusted Total Runoff (Qadj)

As shown in Equation 7, subtract Tv expressed in watershed inches from Q computed in Step 1.

Step 4. Calculate Adjusted Curve Number (CNadj)

Using Qadj and the P corresponding to the return period in question (the P from step 1), calculate the adjusted
CN using Equation 8.

Step 5. Use CNadj in routing calculations for the specific return period in question.

3.2 The Runoff Reduction Method and 80% TSS Combined Methodology

Introduction

The combined methodology has been developed to address the requirement in Tennessee's NPDES Phase II MS4 Permit that states "For projects that cannot meet 100% of the runoff reduction requirement…, the remainder of the stipulated amount of rainfall must be treated prior to discharge with a technology reasonably expected to remove 80% total suspended solids (TSS)." If Runoff Reduction techniques are not acceptable for use on the site as a whole or on portions of a contributing drainage area, the permit requires the remaining rainfall to be treated by practices that remove 80% TSS. This approach allows the designer to apply TSS Reduction Method (TRM) treatment applications to supplement the RRM in order to meet overall compliance on a site. As a note, the site volumetric runoff coefficient, Rv, is calculated using the RRM methodology in Chapter 3.1. The method presented herein is an attempt to bridge the volume requirement (1in.) and the pollutant removal requirement of 80% TSS Reduction.

3.2.1 Site Limiting Conditions

Runoff Reduction Methodology (RRM) is the preferred pathway in complying with the City's water quality criteria. Therefore an attempt to utilize green infrastructure practices, promoting infiltration, capture and reuse of the first inch of rainfall preceded by 72 hours of no measureable rainfall is required. If a site can be designed using RRM GIPs, the designer is to follow the prescribed methodology in Chapter 3.1 of this manual. However, if "site limiting" conditions exist where infiltration practices would negatively affect the landscape and water resources in the area, the TRM methodology may be used to meet the City's water quality criteria upon the City's approval.

Potential site limiting conditions are listed below:

- Where the potential for introducing pollutants into groundwater exists, unless pretreatment is provided;
- Where pre-existing soil contamination is present in areas subject to come in contact with infiltrated runoff;
- Where sinkholes or other karst features are present on the site;
- Where the site has a historic or archaeological significance that cannot be disturbed as determined by the State Historic Preservation Office;
- Where utility conflicts preclude the use of Green Infrastructure Practices;
- Where steep slopes are present and slope failure may occur (stamped geotechnical report must be presented to City Engineer); and
- Other site limitations as determined by the City Engineer.

Cost of implementing green infrastructure/runoff reduction measures shall not be considered a limitation.

3.2.2 TSS Reduction Method

When the use of TSS Removal BMPs is approved by the City, the Runoff Reduction Requirement can be set aside at the value obtained by the site designer using the Runoff Reduction Method to the extent possible. Runoff Reduction should not be dismissed altogether, as the volume captured using the Runoff Reduction Method will be accounted for in calculations for TSS Removal. The remaining volume must then be managed to achieve the Pollutant Removal Performance Standard of 80% TSS Removal. TSS Removal BMPs such as dry ponds, sand filters, and wet ponds can be used for this purpose.

This section provides the policies, tables and equations that will be used to calculate compliance with the Pollutant Removal Performance Standard. Design specifications for TSS Removal BMPs are provided in Section 5.

The TSS Removal BMPs that are deemed acceptable for use to attain the Pollutant Removal Standard are listed in Table 10. The table presents the TSS removal percentage (%) assigned to each BMP, which will be used to calculate the weighted TSS Removal % (weighted TSS) for the capture volume for comparison with the Pollutant Removal Performance Standard. If the weighted TSS ≥ 80%, then the Performance Standard is achieved.

The TSS Removal % values shown in Table 10 are conservative median pollutant reduction percentages for design purposes that have been derived from existing sampling data, modeling and professional judgment. A BMP design may be capable of exceeding these performances; however, the values in the table are median values that can be achieved over time when the structural BMP is sized, designed, constructed and maintained in accordance with required specifications in this manual. The actual % TSS removal value for a BMP in any single storm event may be higher or lower, depending upon a number of factors, including the inflow pollutant concentration, type of storm event, and maintenance condition of the BMP.

Table 10 - Approved TSS PTP Applications

Structural Control	TSS Removal Credit (%)
General Application BMPs	
Stormwater Wet Pond	80
Constructed Wetland	80
Surface Sand Filter	80
Water Quality Swale	80
Limited Application BMPs	
Organic Filter	80
Underground Sand Filter	80
Perimeter Sand Filter	80
Dry Pond	60
Filter Strip	50
Grass Channel	50
Gravity (Oil-Grit) Separator	40

Technical Details

3.2.3 Calculation of % TSS Removal for TSS Removal BMPs in Series

The case of two or more TSS Removal BMPs in series, where stormwater treated in one BMP and discharged into another BMP for further treatment, is called a treatment train. How and why BMPs might be used in series is discussed in Chapter 2 of this Manual. This section presents the calculation of the total % TSS removal for BMPs in series.

Equation 9 shall be used to calculate the total % TSS removal for a treatment train comprised of two or more TSS Removal BMPs.

$$TSS_{train} = TSS_{up} + TSS_{down} - \frac{(TSS_{up} \; x \; TSS_{down})}{100}$$ **Equation 9**

Where:

TSS_{train}	=	TSS Removal % for treatment train (%)
TSS_{up}	=	TSS Removal % for the upstream BMP, from Table 10 (%)
TSS_{down}	=	TSS Removal % for the downstream BMP, from Table 10 (%)

Several situations are possible:

A. For development sites where the treatment train provides the only stormwater treatment on the site, it is required that $TSS_{train} \geq 80\%$ to meet the Pollutant Removal Standard.

B. For development sites that have other TSS Removal BMPs for stormwater treatment that are not included in the treatment train, TSS_{train} must be included in Equation 9 in the calculation of the overall % TSS removal for the site.

C. Equation 9 is not used when the TSS Removal BMP is placed in series with an upstream GIP. While the upstream GIP is considered to provide 100% TSS removal to its storage volume, it's pollutant removal ability is not considered because the Pollutant Removal Performance Standard is applied only to the remainder of the NPDES-MS4 permit stipulated volume (i.e., the volume required to treat the entire 1 inch of rainfall) that is not managed by the GIP. Thus, the storage volume of the GIP is not a part of this remaining volume and so the GIP is not included in the calculation of % TSS removal.

3.2.4 Calculation of % TSS Removal for Flow-through Situations

BMPs within a treatment train may sometimes be separated by a contributing drainage area. In this case, Equation 10 is used, since some of the flow entering the downstream BMP has not been treated by the upstream BMP.

$$\mathbf{TSS_{train}} = \frac{\mathbf{TSS_{up}A_{up}} + \mathbf{TSS_{down}CDA_{down}} + \frac{\mathbf{TSS_{down}CDA_{up}}\left(\mathbf{100} - \mathbf{TSS_{up}}\right)}{\mathbf{100}}}{\mathbf{CDA_{up}} + \mathbf{CDA_{down}}}$$ **Equation 10**

Where:

TSS_{train} = TSS Removal % for treatment train (%)
TSS_{up} = TSS Removal % for the upstream BMP, from Table 9 (%)
TSS_{down} = TSS Removal % for the downstream BMP, from Table 9 (%)
CDA_{up} = Contributing drainage area for the upstream BMP (acres)
CDA_{down} = Contributing drainage area for the downstream BMP (acres)

Several situations are possible:

A. For development sites where the treatment train provides the only stormwater treatment on the site, it is required that $TSS_{train} \geq 80\%$ to meet the Pollutant Removal Standard.

B. For development sites that have other TSS Removal BMPs for stormwater treatment that are not included in the treatment train, TSS_{train} must be included in Equation 10 in the calculation of the overall % TSS removal for the site.

C. Equation 10 is not used when the TSS Removal BMP is placed in series with an upstream GIP because the storage volume of the GIP is not a part of the remaining capture volume that must be treated by the TSS Removal BMP.

3.2.5 Determining the TSS Treatment Volume

There are two basic scenarios for the application of TSS Removal BMPs on a development site, depending on the extent to which the Runoff Reduction Method will be applied at the development and whether the site designer wishes to use a GIP and a TSS Removal BMP in series. If the latter, several different GIP-TSS BMP series combinations can occur depending upon whether one or both of the requirements of the two-pronged Runoff Reduction Performance Standard are met (i.e., weighted Rv ≤ 0.18 and GIPs can capture the entire Tv_{GIP}). The various circumstances that could occur when using TSS Removal BMPs are as follows:

1. **A TSS Removal BMP is used alone on a runoff reduction limited site where no GIPs or Runoff Reduction can be used or achieved -** To calculate the treatment volume needed for the site, the designer will use the following equation:

$$\mathbf{Tv_{TSS} = P \times Rv \times A \times \frac{43560\,\frac{ft^2}{ac}}{12\frac{in}{ft}}} \qquad \textbf{Equation 11}$$

2. **A TSS Removal BMP is used in series with an upstream GIP –** Equations 12, 13 and 14 will be used to calculate the TSS Treatment Volume Tv_{TSS} when a TSS Removal BMP is used in combination with an upstream GIP.

$$\mathbf{Tv_{TSS} = A + B} \qquad \textbf{Equation 12}$$

Where:

Tv_{TSS} = the volume of runoff that must be treated by TSS Removal BMPs to comply with the Pollutant Removal Performance Standard

A = the TSS treatment volume if $Tv_{actual} < Tv_{GIP}$, where:

Tv_{actual} = the actual storage volume of the proposed upstream GIP(s)

Tv_{GIP} = the *entire capture volume from the 1-inch rainfall event*, from Equation 4, presented previously in this Chapter 3.1

If $Tv_{GIP} = Tv_{actual}$, then A = 0. See Equation 13 to calculate A.

B = the TSS treatment volume if the weighted Rv > 0.18 after application of the Runoff Reduction Method. If weighted Rv ≤ 0.18, then B = 0. See Equation 14 to calculate B.

$$\mathbf{A} = \frac{\mathbf{Mult.}\left(\mathbf{P} \times \mathbf{Rv} \times \mathbf{A} \times \dfrac{\mathbf{43560}\,\dfrac{\boldsymbol{ft^2}}{\boldsymbol{ac}}}{\mathbf{12}\,\dfrac{\boldsymbol{in}}{\boldsymbol{ft}}}\right) - \mathbf{Tv_{actual}}}{\mathbf{Mult.}} \qquad \textbf{Equation 13}$$

$$\mathbf{B} = \mathbf{P} \times \mathbf{Rv}(\mathbf{1} - \mathbf{RRCredit}) \times \mathbf{A} \times \frac{\mathbf{43560}\,\dfrac{\boldsymbol{ft^2}}{\boldsymbol{ac}}}{\mathbf{12}\,\dfrac{\boldsymbol{in}}{\boldsymbol{ft}}} \qquad \textbf{Equation 14}$$

Where:

Mult. = the Multiplier for the GIP included in the GIP design specifications in Section 5.

P = the rainfall depth, 1 inch

Rv = the weighted Rv of the contributing drainage area to the GIP. (e.g., if the entire contributing drainage area to the GIP is impervious, then Rv = 0.95.) Use tables and equations in Chapter 3.1 of this Section to assist in the calculation of Rv.

A = the contributing drainage area to the GIP or BMP (acres)

Tv_{actual} = the treatment volume that can be captured by the upstream GIP(s)

RRCredit the runoff reduction credit for the GIP that is located upstream of the TSS Removal BMP, Table 5.

Equations 12, 13 and 14 can be combined to form Equation 15.

$$\mathbf{Tv_{TSS}} = \left[\frac{\mathbf{Mult.}\left(\mathbf{P} \times \mathbf{Rv} \times \mathbf{A} \times \dfrac{\mathbf{43560}}{\mathbf{12}}\right) - \mathbf{Tv_{actual}}}{\mathbf{Mult.}}\right] + \left(\mathbf{P} \times \mathbf{Rv}(\mathbf{1} - \mathbf{RRCredit}) \times \mathbf{A} \times \frac{\mathbf{43560}}{\mathbf{12}}\right) \qquad \textbf{Equation 15}$$

There are several possible combinations for GIPs and BMPs working in series. Table 11 lists the combinations and the form of Equation 12 that is used.

Table 11 - Possible GIP-TSS Series Combinations			
Scenario	Complies with Runoff Reduction Performance Standard?		Form of Equation 12 that is used to calculate Tv_{TSS}
	$Rv \leq 0.18$	GIPs capture entire Tv_{GIP}	
GIP-TSS Combination 1	No	Yes	$Tv_{TSS} = B$
GIP-TSS Combination 2	Yes	No	$Tv_{TSS} = A$
GIP-TSS Combination 3	No	No	$Tv_{TSS} = A + B$

The following examples show how Equations 12 through 15 are applied to developments to determine the TSS treatment volume.

EXAMPLE 5 GIP-TSS Combination 1

A site designer performing water quality calculations for a 3 acre commercial parking lot development that is runoff reduction limited. A Level 1 infiltration trench on C soil (Table 5: RR Credit = 50%) manages the Tv_{GIP} for the rainfall that falls on the 2.5 acre parking lot but does not lower the weighted Rv for the site sufficiently to achieve Rv ≤ 0.18. The use of other GIPs is not feasible so the designer plans to place a wet pond downstream of the infiltration trench to further handle the runoff. The area of the infiltration trench is 0.2 acres and it has an Rv = 0.04 (Forest on C soil). For the purpose of water quality calculations, the area of the wet pond (0.3 acres) is not included. (Note, this area is typically included for channel protection and peak flow calculations.) Determine the treatment volume for the wet pond.

The Rv for the contributing drainage area to the GIP is determined using Equation 1:

$$\text{Weighted Rv} = \frac{(0.95 \times 2.5\text{ ac}) + (0.04 \times 0.2\text{ ac})}{(2.7\text{ ac})} = 0.88$$

The treatment volume of the wet pond is calculated using Equation 14 (or Equation 15), where A = 0 because the parking lot has sufficient storage volume to manage Tv_{GIP}. So, Equation 15 becomes:

$$Tv_{TSS} = P \times Rv(1 - RRCredit) \times A \times \frac{43560}{12} = 1 \times 0.88(1 - 0.50) \times 2.7ac \times \frac{43560}{12}$$

$$Tv_{TSS} = 4{,}312\text{ ft}^3$$

Note that the % TSS Removal for the wet pond = 80%, so a properly sized pond will be sufficient to meet the Pollutant Removal Performance Standard of 80% TSS Removal.

EXAMPLE 6 GIP-TSS Combination 2

A site designer performing water quality calculations for a 5 acre development that is runoff reduction limited. The site's weighted Rv is less than 0.18 due to the use of a Level 2 bioretention GIP, but it does not have sufficient storage volume available to capture the entire volume from the 1 inch rainfall. The land cover at the development is as follows: 4 acres of impervious surface (Rv = 0.95) and 1 acre of forest on C soil (Rv = 0.04). The entire development discharges to Level 2 bioretention GIPs which will capture no more than 8,500 ft^3 of runoff. Overflow from the GIPs discharge to a wet pond. Determine the treatment volume for the wet pond.

The weighted Rv for the development without consideration of the GIPs or the TSS Removal BMP is determined using Equation 1.

$$\text{Weighted Rv} = \frac{(0.95 \times 4\text{ ac}) + (0.04 \times 1\text{ ac})}{(5\text{ ac})} = 0.77$$

The Weighted Rv for the site after Level 2 bioretention GIPs are applied is as follows:

$$\text{Weighted Rv} = \frac{(0.95 \times (1 - 0.80) \times 4\text{ ac}) + (0.04 \times 1.0\text{ ac})}{(5\text{ ac})} = 0.16$$

The required treatment volume for the development is calculated using Equation 13 (or Equation 15), where B = 0 because Rv was less than 0.18. So, Equation 15 becomes:

$$\text{Tv}_{\text{TSS}} = \left[\frac{\text{Mult.}\left(\text{P} \times \text{Rv} \times \text{A} \times \frac{43{,}560}{12}\right) - \text{Tv}_{\text{actual}}}{\text{Mult.}}\right]$$

$$\text{Tv}_{\text{TSS}} = \left[\frac{1.25\left(1 \times 0.77 \times 5\text{ac} \times \left(\frac{43560}{12}\right)\right) - 8{,}500\text{ ft3}}{1.25}\right]$$

$$\text{Tv}_{\text{TSS}} = \frac{17{,}469\text{ft}^3 - 8{,}500\text{ft}^3}{1.25} = 7{,}176\text{ ft}^3$$

Note that the % TSS Removal for the wet pond = 80%, so a properly sized pond will be sufficient to meet the Pollutant Removal Performance Standard of 80% TSS Removal.

EXAMPLE 7 GIP-TSS Combination 3

A site designer performing water quality calculations for a 4.5 acre development that is runoff reduction limited. The site's weighted Rv is 0.30 due to the use of a Level 2 water quality swale GIP to treat the 2.5 acre impervious area. The site does not have sufficient storage volume available to capture the entire volume from the 1 inch rainfall in the GIP and an Rv of 0.18 has not been met. The land cover at the development is as follows: 2.5 acres of impervious surface (Rv = 0.95) and 2.0 acres of meadow/turf on C soil (Rv = 0.20). The entire development discharges to the Level 2 water quality swale GIP which can capture no more than 5,500 ft^3. Overflow from the GIP discharges to a wet pond. Determine the treatment volume for the wet pond.

The weighted Rv for the development without consideration of the GIP or the TSS Removal BMP is determined using Equation 1.

$$\text{Weighted Rv} = \frac{(0.95 \times 2.5\ \text{ac}) + (0.20 \times 2.0\ \text{ac})}{(4.5\ \text{ac})} = 0.61$$

The Weighted Rv for the site after a Level 2 water quality swale GIP is applied is as follows:

$$\text{Weighted Rv} = \frac{(0.95 \times (1 - 0.60) \times 2.5\ \text{ac}) + (0.20 \times 2.0\ \text{ac})}{(4.5\ \text{ac})} = 0.30$$

The required treatment volume for the development is calculated using Equation 15:

$$\text{Tv}_{\text{TSS}} = \left[\frac{\text{Mult.}\left(\text{P} \times \text{Rv} \times \text{A} \times \frac{43{,}560}{12}\right) - \text{Tv}_{\text{actual}}}{\text{Mult.}}\right] + \left(\text{P} \times \text{Rv}(1 - \text{RRCredit}) \times \text{A} \times \frac{43560}{12}\right)$$

$$\text{Tv}_{\text{TSS}} = \left[\frac{1.1\left(1 \times 0.61 \times 4.5\ \text{ac} \times \left(\frac{43{,}560}{12}\right)\right) - 5{,}500\ \text{ft}^3}{1.1}\right] + \left(1 \times 0.61(1 - 0.60) \times 4.5\ \text{ac} \times \frac{43560}{12}\right)$$

$$\text{Tv}_{\text{TSS}} = \frac{10{,}961\text{ft}^3 - 5{,}500\text{ft}^3}{1.1} + 3{,}986\ \text{ft}^3 = 8{,}951\text{ft}^3$$

Note that the % TSS Removal for the wet pond = 80%, so a properly sized pond will be sufficient to meet the Pollutant Removal Performance Standard of 80% TSS Removal.

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