City of Birmingham, AL

Post Construction Storm Water Design Manual

Version March 2019

Chapter 6. GIP and BMP Design Specifications

Appendices

Chapter 1. The Need for Storm Water Management

LID techniques and GIPs rely on the mechanisms of infiltration and evapotranspiration to manage storm water on a land development.

Storm Water Overview

Runoff Reduction and Pollutant Removal Capability

The City makes every effort to consistently meet clean water standards.

The City is addressing aging infrastructure, storm water quality, drainage, and flooding issues through LID, GI, GIPs, and BMPs.

City Standards Emphasize LID and GI

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1.1 Introduction

1.1.1 Manual Overview

The *City of Birmingham Post Construction Storm Water Design Manual* provides: information on the development planning process; relevant policies, requirements, and plans; the roles and requirements of the City and other agencies that have a role in the development process; guidance about incorporating Low Impact Development (LID) practices for storm water management into site developments; and structural and intrinsic Green Infrastructure Practices (GIPs) and Total Suspended Solids (TSS) Removal Best Management Practices (BMPs) that must be implemented to manage storm water and land development subject to the *City of Birmingham Post Construction Storm Water Ordinance.* This manual is designed to provide land developers and designers with all the information required to effectively address and control both storm water quality and quantity using an integrated approach to land development.

1.1.2 Manual Objective

The objective of the *City of Birmingham Post Construction Storm Water Design Manual* is to provide policies, procedures, and guidance for the management of storm water quality (i.e., pollutants and volume) and quantity (i.e., peak discharge and volume) on developed lands, ***after*** construction is complete. This manual supports the *City of Birmingham Post Construction Storm Water Ordinance.*

To meet this objective, this manual provides comprehensive guidance for land developers and site designers on storm water management approaches for site design that will better protect Birmingham's citizens, business, and natural resources from the negative impacts of land development and nonpoint source pollution (i.e., street and property flooding, stream channel and ditch erosion, and water pollution). This manual is a key component in managing storm water in the City of Birmingham.

This manual does provide guidance on construction site sediment control and sequencing, specifically as it pertains to certain GIPs and BMPs that are sensitive to sediment inflows and soil compaction. However, this manual does not provide sufficient guidance to fully support local or state requirements for storm water management during construction (i.e., sediment and erosion control, construction site waste control, etc.). Site designers are strongly urged to consult Birmingham's *Soil Erosion and Sediment Control Ordinance* (Ord. No. 99-131) and the Alabama Department of Environmental Management (ADEM) Construction General Permit (General NPDES Permit No. ALR100000) for local and state requirements, respectively. Additional guidance on construction site storm water can be found in the *Alabama Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas* (ASWCC, 2003) and the *Alabama LID Handbook* (ADEM, no date).

1.1.3 Target Audience

The *City of Birmingham Post Construction Storm Water Design Manual* is provided specifically for developers and site designers to use when designing storm water management practices for developing land in the City of Birmingham. For this manual, the term "site designers" can refer to any of the team of people who assist or support the developer with the design or construction of storm water management systems and controls at a land development. This can include civil and other engineers, landscape architects, land planners, environmental technicians, hydrologists, soil scientists, and hydrogeologists. This manual provides policies, technical guidance, and land design support tools on the preparation of land development design plans, the use of LID planning techniques, hydrologic techniques, selection and design of appropriate GIPs and TSS Removal BMPs, and drainage (hydraulic) design.

1.1.4 Regulatory Status of the Manual

This manual is authorized by the *City of Birmingham Post Construction Storm Water Ordinance* to establish rules, regulations, and technical guidelines for storm water management design, construction, inspection, and maintenance on land developments in the City of Birmingham. This manual was developed consistent with the ordinance and for the purpose of enforcing the provisions of the ordinance. This manual is enforceable, consistent with the authorities and enforcement provisions of the ordinance.

1.1.5 How to Use This Manual

This manual provides policies, performance standards, technical design guidance, and support tools to aid developers and site designers with compliance with the *City of Birmingham Post Construction Storm Water Ordinance*. A guide to the chapters in this manual is provided below.

- **Chapter 1** provides general information on the objective, purpose, and use of the manual; presents an overview of the impacts of storm water runoff in the City, the benefits of storm water management, and the development of storm water management rules and regulations; and introduces the concepts of LID planning, GIPs, and TSS Removal BMPs to meet storm water quality objectives.
- **Chapter 2** details the various federal, state, and local programs and regulations that can influence storm water management for land developments and also provides storm water management-related information and support tools to assist developers and site designers as they navigate Birmingham's site design and plan approval process.
- **Chapter 3** presents the overarching set of performance standards and associated policies for storm water management planning and design on qualifying land developments in the City of Birmingham.
- **Chapter 4** provides a comprehensive set of design policies, required calculations, and associated design guidance for GIPs, BMPs, and the on-site storm water system, including storm water hydrology, storm water quality calculations, channel protection calculations, peak flow calculations, and storm water drainage system design.
- **Chapter 5** focuses on LID techniques and processes, including general principles, planning practices, and Birmingham-specific LID and GIP incentives and credits.
- **Chapter 6** presents the detailed design specifications and associated guidance and specifications that must be used by site designers in the design of GIPs and BMPs.
- **Chapter 7** establishes the inspection and maintenance responsibilities for storm water system components during the construction process and also provides general guidance on construction site management techniques when LID techniques and GIPs are included on the site. *Chapter 7 is being developed for a future version of this manual.*

1.1.6 Contact Information

This manual was developed and is administered by the City of Birmingham Department of Planning, Engineering & Permits. Questions regarding the *City of Birmingham Post Construction Storm Water Ordinance* and this manual should be provided to the Storm Water Management Department. Contact information is as follows:

Phone	(205) 254-2000
Address	Storm Water Management Department of Planning, Engineering & Permits 710 North 20th Street Birmingham AL 35203
Email	PostStorm@birminghamal.gov

1.2 Understanding Storm Water

Portions of the text in this section were taken from the *Georgia Stormwater Management Manual* (ARC, 2016) and adapted for use in Birmingham.

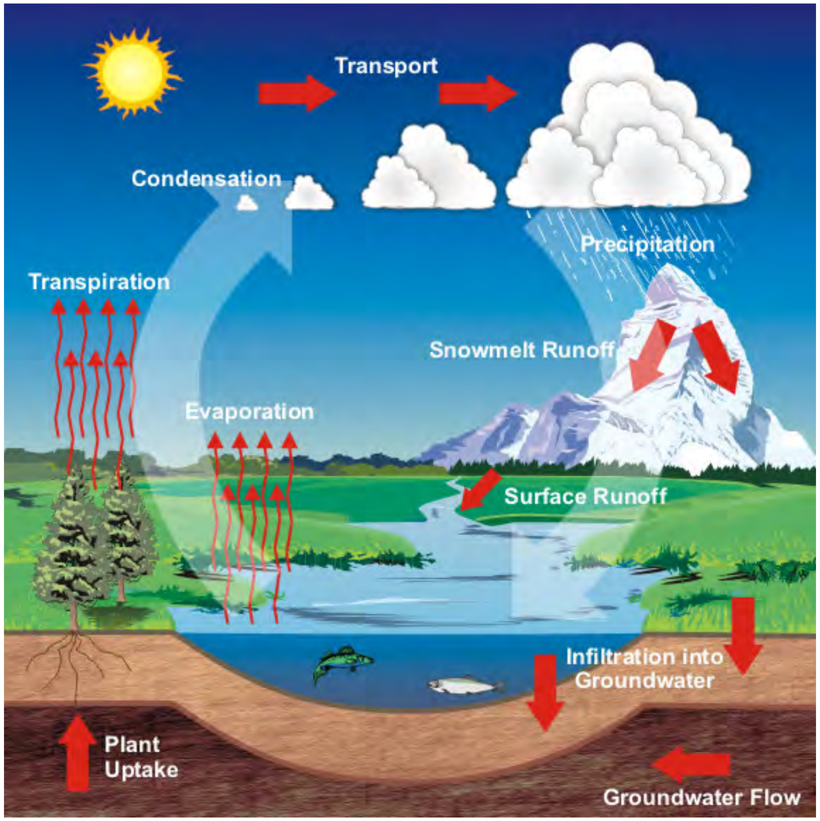
1.2.1 What Causes Storm Water?

Storm water (also called "storm water runoff" or just "runoff") is caused by rain that falls to the ground and does not infiltrate into the soil. The amount of storm water that occurs during a rainfall depends on several factors including the amount of rain that falls and how quickly or intensely it falls, the moisture condition of the soil prior to rainfall, and the land cover in the area where the rain falls. Subsurface conditions, such as the elevation of the groundwater table or the presence and location of clay layers in the soil, can also play a role in the volume of storm water that is generated for any given rainfall event.

Of all these factors, land cover is particularly unique in that it is the only factor that is controlled entirely by man. In fact, the general type of land cover (i.e., trees and woody vegetation, grass, bare soil, or pavement and rooftops) plays a significant role in the generation of runoff. There is a clear and measurable link between land cover changes and the volume, peak magnitude, timing, and velocity of storm water discharges. In general, more pavement and rooftops will equate to more runoff volume and faster runoff flows.

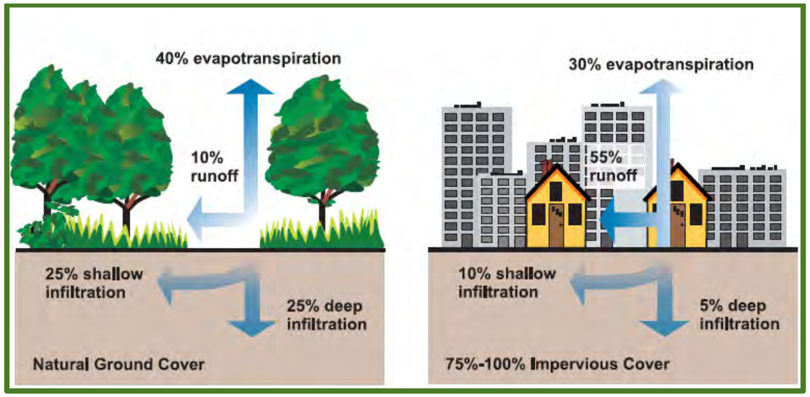
Natural landscapes in Alabama (typically a mix of trees, vegetation, and different types of soil) are highly capable of managing rainfall for most storms without generating a significant amount of storm water. Leaves intercept and evaporate rainfall; plant roots draw up the water for photosynthesis; and natural, un-compacted soil allows rainfall infiltration, even in sticky, clay-laden soils. The rainfall that soaks into the soil is taken up by plant roots for photosynthesis; moves laterally to provide base flow (dry weather flow) for nearby streams, ponds or lakes; or moves through the soil and replenishes the groundwater. Hilly terrain and natural depressions in the ground surface slow and provide temporary storage for any storm water that is generated. These actions naturally limit and slow storm water, inherently providing for the overall health and well-being of local streams, lakes, and other waterbodies. Natural landscapes are a primary component of the earth's hydrologic cycle (**Figure 1-1**).

Figure 1-1. The Hydrologic Cycle *(Source: creativecommons.org)*



In contrast, developed lands produce storm water more quickly and in larger volumes than most natural landscapes. **Figure 1-2** compares the relative the amount of rainfall managed by natural means (infiltration and evapotranspiration) and the subsequent percentage of runoff produced for both natural and developed areas.

Figure 1-2. Runoff Increases from Natural & Developed Land Cover
(Source: epa.gov)



As land is developed, forests and farmlands are replaced by shopping areas, centers of business and industry, schools and churches, and residential areas. The hydrology, or the natural cycle of water moving through the earth and its atmosphere, is disrupted and altered. Grading flattens hilly terrain and fills in natural depressions that once directed and slowed storm water. Impervious surfaces replace trees and plants that once used rainfall. The topsoil and organic matter that once infiltrated rainfall are scraped and removed, and the remaining subsoil is compacted. The loss of the original topsoil and vegetation removes the ability of the landscape to intercept, evaporate, infiltrate, and filter rainfall. Rainfall that once evaporated and seeped into the soil now runs across the ground much more readily, increasing the amount of storm water that is delivered to local waterways.

The role that soil and vegetation can play in storm water management for urban and suburban landscapes must not be underestimated. When properly protected and managed, soil and vegetation can provide substantial storm water volume reduction even on urban developments. Many of the storm water controls included in this design manual use soil and vegetation to control storm water quality and, to a lesser degree, quantity.

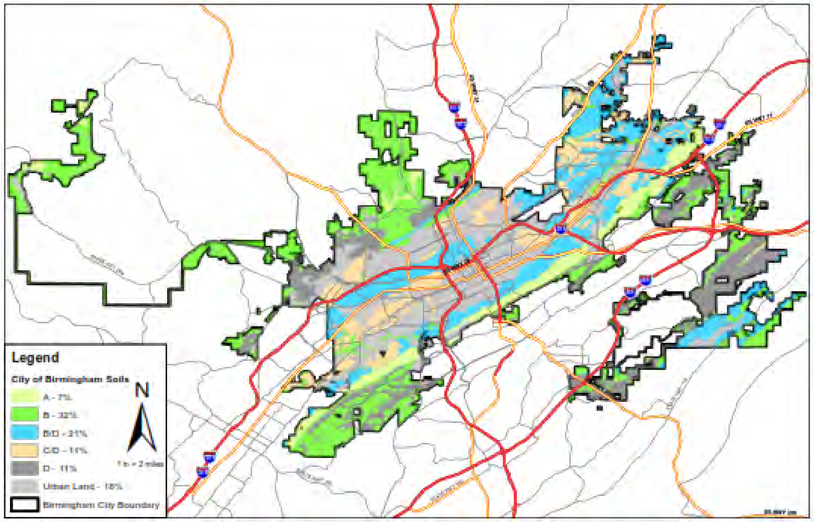
Soil and vegetation work to some degree in a self-maintaining cycle such that the health of one affects the health (and therefore storm water capabilities) of the other. Well-drained and moderately well-drained soils have numerous void spaces that can store and transmit water beneath the surface crust, distribute the water downward, and support water and nutrient uptake through plant roots, thus removing rainfall and pollutants. Healthy soil also has fauna, flora, and chemical characteristics that support plant life. Additionally, strong and vigorous root growth from healthy vegetation helps keep soil permeable and aids in infiltration. Clearly, using un-compacted soil, choosing the right plants, and keeping both soil and plants healthy will help to ensure that storm water practices perform most effectively.

LID techniques and GIPs rely on the mechanisms of infiltration and evapotranspiration to manage storm water on a land development. As a result, when implementing LID and/or GIPs, soil and vegetation are considered site and storm water design elements, which must meet certain criteria. For soil, these criteria include the hydrologic soil group (HSG), permeability, and infiltration rate. LID and GIPs are discussed more fully later in this chapter and then throughout this manual.

Figure 1-3 presents a map of HSGs and urban soils (i.e., non-native, compacted soils) in Birmingham. The legend indicates the percent of land in Birmingham comprised of each soil, showing that 60% of land in Birmingham is covered by A, B, or B/C soil groups, which, ideally, readily infiltrate storm water. When developing in these areas, native soil preservation can be a low-cost, highly effective approach to on-site storm water management. Even in soils that do not readily infiltrate (C/D and D soils), GIPs can be used with underdrains to ensure adequate infiltration and storm water management. It is likely that vegetation mapping would show a similar result, i.e., that Birmingham has a large amount of vegetation that, in the right circumstances, could be used to manage storm water.

This design manual includes design specifications and guidance for both soil and vegetation for the GIPs that use them as design elements. This information is provided in Chapter 6.

Figure 1-3. Hydrologic Soil Groups & Urban Soils in Birmingham, AL



1.2.2 The Impacts of Storm Water on Waterbodies

Increased amounts of storm water and faster runoff flows resulting from land development do have an impact on the physical, chemical, and biological conditions of our local streams, rivers, and lakes. Under normal hydrologic conditions, natural landscapes use rainfall to replenish sub-surface aquifers, provide base flow for streams and other waterbodies, and support plant and animal life. Soil along stream banks and beds is anchored in place with plants, trees, and rocks. The flora and fauna that live along and within streams are well-suited to the occasional inflows of storm water that naturally occur. As a result, streams, lakes, and other waterbodies are generally compatible with the surrounding landscape and remain fairly stable physically, chemically, and biologically.

As land development and associated impervious surfaces increase, the circumstances for waterbodies that receive storm water inflows can change dramatically, resulting in several impacts:

1. Changes in stream hydrology and hydraulics,
2. In-stream erosion and sedimentation, and
3. Impacts to aquatic habitats.

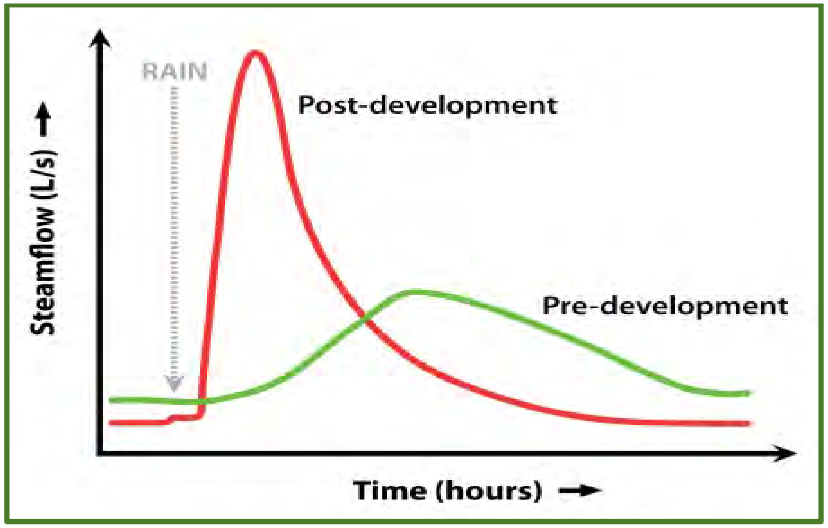
Changes in stream hydrology and hydraulics. Urban development alters the hydrology of watersheds and streams by disrupting the natural water cycle, which typically results in the negative impacts summarized below.

- **Increased Storm Water Volumes** – Land surface changes can dramatically increase the total volume of storm water generated.
- **Increased Storm Water Peak Discharges** – Increased peak discharges of storm water for a developed watershed can be two to five times higher than those for an undeveloped watershed.
- **Greater Storm Water Velocities** – Impervious surfaces and compacted soils, as well as improvements to the drainage system such as storm drains, pipes, and ditches, increase the speed at which rainfall runs off land surfaces within a watershed.
- **Altered Timing** – As storm water velocities increase, it takes less time for water to run off the land and reach a stream or other waterbody.
- **Increased Frequency of Stream Overtopping** – Increased storm water volumes and peak flows increase the frequency and duration of bank full events, which are the primary channel forming events.
- **Increased Flooding** – Increased storm water volumes and peaks also increase the frequency, duration, and severity of out-of-bank flooding.

❖ **Lower Base Flows (Dry Weather Flows)** – Reduced infiltration of storm water causes streams to have less base flow during dry weather periods and reduces the amount of rainfall recharging groundwater aquifers.

Streams in developed areas are often characterized as very "flashy" or "spiky" because of the increased volume of storm water, greater peak flows, and quicker hydrologic response to storms. This translates into the sharp peak and increased size of the post-development hydrograph, as shown in **Figure 1-4**.

Figure 1-4. Runoff Hydrograph Differences *(Source: mde.state.md.us)*



Intentional alterations to streams have impacts as well. Bridges and culverts are built to accommodate development. Buildings and roadways are placed in natural floodplains. These activities can negatively affect stream hydraulics and decrease the floodplain's natural storage capacity. These changes, combined with the increase in storm water flows to the stream, can result in natural streams and floodplains proving inadequate for the new hydrology, resulting in the inundation of land that did not previously experience flooding (**Figure 1-5**).

Figure 1-5. Overbank Flooding in Columbiana, AL *(Source: wbrc.com)*

Changes to stream geometry and in-stream erosion. Streams in urbanizing areas cannot tolerate the high volume, fast flows of runoff that they experience after storm events. Although these flows are short-lived, they occur more and more frequently as land continues to develop, becoming faster and stronger. Storm flows will wash away the vegetation, rocks, tree roots, and other features that anchored stream beds and banks, and the stream will begin to erode, directly impacting the physical shape and character of the waterway. Some of the common impacts of urban development are summarized below.

❖ **Stream Widening and Bank Erosion** – Stream channels widen to accommodate and convey the increased storm water and higher stream flows from developed areas. More frequent small and moderate storm water events undercut and scour the lower parts of the stream bank, causing the steeper banks to erode and collapse during larger storms. Higher flow velocities further increase stream bank erosion rates. A stream can widen to many times its original size due to post-development storm water (**Figure 1-6**).

Figure 1-6. Parkerson Mill Creek Erosion, Auburn AL *(Source: Storm Water Solutions Newsletter, Feb. 6, 2017)*

- **Stream Downcutting** – Streams can also accommodate high post-construction flows by downcutting the streambed. This causes instability in the stream profile, or elevation along a stream's flow path, which increases velocity and triggers further channel erosion both upstream and downstream.

To combat in-stream erosion and downcutting, many local governments armor urban streams with large rocks, concrete walls, and even concrete channels. In these cases, the ability of the stream to adapt naturally to its new urban, suburban flow conditions is reduced or often eliminated entirely (**Figure 1-7**).

Figure 1-7. In-Stream Erosion Impacts

Left: In-stream erosion and downcutting in a suburban area *(Source: watershedconservation.org)*

Right: Urban stream, fully lined with concrete *(Credit: Ian Wright)*

- **Loss of Riparian Tree Canopy** – As stream banks are gradually undercut and slump into the channel, trees that had protected the banks are exposed at the roots. This leaves trees less stable and more likely to be uprooted during major storms, which further weakens bank structure.
- **Changes in Channel Bed Due to Sedimentation** – Due to channel erosion and other sources upstream, sediments are deposited in the stream as sandbars and other features, covering the channel bed, or substrate, with shifting deposits of mud, silt, and sand.
- **Increase in Floodplain Elevation** – To accommodate the higher peak flow rate, a stream's floodplain elevation typically increases following development in a watershed. This problem is compounded by the placement of structures (e.g., buildings or roads) in floodplains, which causes flood heights to rise even

further. Property and structures that had not previously been subject to flooding may subsequently be placed at risk.

Impacts to Aquatic Habitat. Along with changes in stream hydrology and morphology, the habitat value of streams diminishes due to development in a watershed. Common impacts on habitat are summarized in the bullets below.

- **Degradation of Habitat Structure** – Higher and faster flows due to development can scour channels and wash away entire biological communities. Stream bank erosion and the loss of riparian vegetation reduce habitat for many fish species and other aquatic life, while sediment deposits can smother bottom-dwelling organisms and aquatic habitat.

- **Loss of Pool-Riffle Structure** – Streams draining undeveloped watersheds often contain pools of deeper, more slowly flowing water that alternate with "riffles" or shoals of shallower, faster flowing water. These pools and riffles provide valuable habitat for fish and aquatic insects. As a result of the increased flows and sediment loads from urban watersheds, these pools and riffles can disappear and be replaced with more uniform (and often shallower) streambeds that provide less varied aquatic habitats.

- **Reduced Base Flows** – Reduced base flows due to increased impervious cover in a watershed and the loss of rainfall infiltration into the soil and water table adversely affect in-stream habitats, especially during periods of drought.

- **Increased Stream Temperature** – Storm water from warm impervious areas, storage in impoundments, loss of riparian vegetation, and shallow channels can all cause an increase in temperature in urban streams. Increased temperatures can reduce dissolved oxygen (DO) levels and disrupt the food chain. Certain aquatic species can only survive within a narrow temperature range.

- **Decline in Wildlife Abundance and Biodiversity** – When there is a reduction in various habitats and habitat quality, both the number and the variety, or diversity, of organisms (wetland plants, fish, macro invertebrates, etc.) are also reduced. Sensitive fish species and other life forms disappear and are replaced by those organisms that are better adapted to the poorer conditions. The diversity and composition of benthic (or streambed) habitats have frequently been used to evaluate the health of urban streams. Aquatic insects are also a useful environmental indicator as they are sensitive to changes in water quality.

Water Quality Impacts. A major source of water quality impacts in streams, lakes, and other waterbodies is storm water. Water quality degradation in urbanizing watersheds starts when development begins. Erosion from construction sites and other disturbed areas contributes large amounts of sediment to streams. As construction and development proceed, impervious surfaces replace the natural land cover, and pollutants from human activities begin to accumulate on these surfaces. As storm water discharges from rooftops and travels over driveways, parking lots, yards, and roads, it picks up more sediment and other pollutants such as litter, pathogens from animal waste and leaky sewers or septic systems, pesticides and herbicides used on lawns and landscapes, oils and greases from cars and industries, dusts, and other substances. These pollutants are carried in the runoff to local waterways where they can have a myriad of impacts.

- **Sediments** – Eroded soils are a common component of urban storm water and are a pollutant in their own right. In fact, the single most important water quality problem in the United States is sediment dislodged from exposed soil, stream channel banks, and channel beds (Neary, et al., 1989). Excessive sediment can be detrimental to aquatic life by interfering with photosynthesis, respiration, growth, and reproduction. Sediment particles transport other pollutants that are attached to their surfaces such as nutrients, metals, and hydrocarbons.

- **Nutrients** – Runoff from urban and rural watersheds can contain increased nutrients such as nitrogen and/or phosphorus compounds. Increased nutrient levels can be a problem as they promote weed and algae growth in lakes and streams. Algae blooms can block sunlight from reaching underwater grasses and deplete oxygen when the organic matter decomposes (eutrophication; **Figure 1-8**).

Figure 1-8. Algal Bloom *(Source: AL Cooperative Extension Service)*

- **Pathogens** – Pathogens harmful to human health in natural waters may consist of bacteria, protozoa, viruses, and other microscopic organisms. The sources of pathogens in urban storm water and streams may be leaking private or public sewer lines, combined sewer overflows, malfunctioning septic tanks, animals, pets, and birds. Agricultural runoff from livestock management areas, manure spreading, and concentrated animal feeding operations (CAFOs) can also contribute to pathogenic contamination.

- **Hydrocarbons** – Oils, greases, and gasoline contain a wide array of hydrocarbon compounds, some of which have been shown to be carcinogenic, tumorigenic, and mutagenic in various species of fish and other lifeforms. In large quantities, oil can impact drinking water supplies and affect recreational use of waters. Oils and other hydrocarbons wash off roads and parking lots, primarily due to vehicle leaks. Other sources include improper disposal of motor oil in storm drains and streams, spills at fueling stations, and restaurant grease traps.

- **Reduced Oxygen in Streams** – The decomposition process of organic matter uses up DO in the water, which is vital for fish and other aquatic life. As organic matter in the watershed is taken up by storm water and conveyed to receiving waters, and as weed and algae growth occurs due to increased nutrient loading, DO levels can be rapidly depleted. If DO deficiency is severe enough, fish kills may occur, and stream life can weaken and die. In addition, oxygen depletion can affect the release of toxic chemicals and nutrients from sediments deposited in a waterway. All forms of organic matter in urban storm water like leaves, grass clippings, and pet waste contribute to this problem. Additionally, there are non-storm water discharges of organic matter to surface waters such as sanitary sewer leakage and septic tanks leaching. While organic material is necessary for aquatic life, an overabundance of organic matter can contribute to these challenges.

- **Toxic Materials** – Besides oils and greases, urban storm water runoff can contain a wide variety of other toxicants and compounds, including heavy metals like lead, zinc, copper, and cadmium, as well as organic pollutants that include pesticides, polychlorinated biphenyls (PCBs), and phenols. These contaminants are of concern because they are toxic to aquatic organisms and can bio-accumulate in the food chain. Many toxicants accumulate in the sediments of streams and lakes. Sources of these contaminants include industrial and commercial sites, urban surfaces like rooftops and roadways, vehicles and other machinery, improperly disposed household chemicals, landfills, hazardous waste sites, and atmospheric deposition.

- **Thermal Pollution** – As storm water flows over impervious surfaces, such as asphalt and concrete, it increases in temperature before reaching a stream or pond. Water temperatures are also increased due to shallow ponds and impoundments along a watercourse and fewer trees along streams to shade the water. Since warm water holds less DO than cold water, this "thermal pollution" further reduces oxygen levels in urban streams. Temperature changes can severely impact certain aquatic species, such as trout and stoneflies, which can survive only within a narrow temperature range.

- **Trash and Debris** – Considerable quantities of trash and other debris are washed through storm drain systems and into streams and lakes. The presence of trash is an indicator of other anthropomorphic effects on water quality, stream structure, and aquatic habitat. Terrestrial and aquatic animals can be harmed when they consume or become entangled/engulfed in solid waste.

1.2.3 Impacts on Communities

The storm water impacts of land development and gradual urbanization on local communities can be significant if not mitigated. These issues range from physical to environmental to economic, but all of them stem from two primary impacts: increased flooding and reduced water quality. Community impacts are summarized in the following paragraphs.

- **Increased Flooding** – As more land development occurs without proper storm water management, our natural and man-made infrastructure becomes more vulnerable to flooding, which is a result of the increased storm water peak flow rates and volumes resulting from the land development.

- **Environmental Issues** – As pollutants in storm water enter waterways, they threaten aquatic life and drinking water supplies, can contribute to human illness, and damage the tourism and recreation economies within the city.

- **Economic Challenges** – Local governments are typically charged with resolving the flooding, erosion, and environmental issues caused by increased storm water. The financial cost to repair known issues and prevent further occurrences can sometimes be significant, competing directly against other government priorities (e.g., police, fire, schools) for funding.

- **Declining Property Values** – Storm water pollution affects the appearance and quality of downstream waterbodies, influencing the desirability of working, living, traveling, or owning property near the water. Furthermore, the value of property located in areas with a high potential or increasing history of flooding will also decrease.

- **Loss of Fisheries** – Certain toxic chemicals present in streams, lakes, and rivers as a result of polluted storm water inflows can accumulate in fish, especially in older and larger fish. When chemical concentrations are elevated in fish, they can pose health risks to people who eat them.

- **Reduced Drought Resiliency** – Increased storm water volumes resulting from land development reduces the amount of rainfall available to recharge shallow groundwater aquifers and feed freshwater rivers and streams during dry weather. Thus, streams have lower base flow and are less able to withstand extended periods of drought.

- **Increased Litigation** – Legal action can be brought against local governments that have not adequately addressed storm water drainage and water quality problems.

- **Reduction in Quality of Life** – Storm water quantity and quality impacts can reduce the quality of life in a community, making it a less desirable place to live, work, and play.

1.2.4 Impacts in Birmingham

Storm water impacts similar to those described in the previous sections have been documented in the City of Birmingham since the 1920s.

With the construction of Birmingham's earliest industries, blast furnaces and rolling mills for making steel, the City's population increased eightfold from 1880 to 1890. The construction of "modern" iron and steel mills in the early 20th century contributed to such a rapid population growth that Birmingham earned the nickname "The Magic City" (Robinson, et al., 1953; **Figure 1-9**). These early iron and steel industries, along with their supporting businesses and residential villages, developed along the edges of local streams, primarily Village and Valley Creeks, to take advantage of the readily available water resources (Connerly, 2005). By 1925, misuse and neglect of these streams was evident to such an extent that a city-wide park plan, *A Park System for Birmingham* (**Figure 1-10)**, noted Village Creek had become a "storm-water drainage channel," prone to periodic flooding. The plan predicted that flooding problems would continue to get worse as development continued (Olmstead Brothers, 1925).

Figure 1-9. Woodward Iron Company, Founded in 1881 *(Source: encyclopediaofalabama.org)*

Figure 1-10. Olmstead Bros. Park Plan *(Source: trekbirmingham.com)*

By the 1970s, flooding throughout the heart of the City had increased so significantly that United States Army Corps of Engineers (USACE) estimated annual property losses in Birmingham at $2.5 million (USACE, 1981). In an attempt to alleviate the flooding issues and improve water quality and aesthetic appeal, the United States Senate Public Works Committee authorized a feasibility study on Village Creek in 1971. The study recommended a mix of structural and nonstructural alternatives while noting that no action would result in continued property loss, floods that threatened loss of life, prolonged degradation of water quality, further effects to terrestrial ecosystems and creek aesthetics, and continued deterioration and blight in creek-adjacent neighborhoods, of which flooding and related impacts were partially to blame (USACE, 1981).

The ultimate result of the 1971 USACE study was a decades-long flood buyout program that culminated in the acquisition and relocation of more than 1,200 properties from the floodplain while permanently preserving those areas as parks and open space (**Figure 1-11**). The buyout program incurred a cost of approximately $15 million in cash and in-kind contributions from the City of Birmingham in addition to approximately $60 million leveraged in federal funding (Revell, et al., 2008).

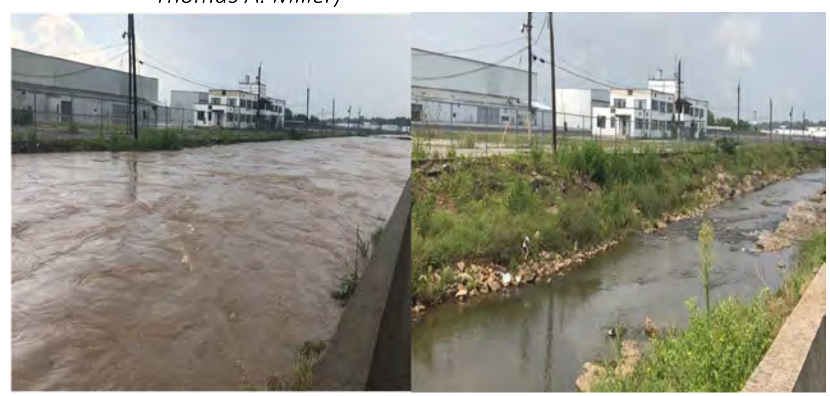
Figure 1-11. St. James Baptist Christian Center Before / After Acquisition and Relocation *(Source: floodsciencecenter.org)*

In addition to storm water impacts resulting from industrialization and development along stream banks and in floodplains during Birmingham's early growth periods, increased urbanization of the city center coupled with urban sprawl resulting from construction of interstate and highway corridors extending outward from the City's core have also played a significant role in challenges posed by storm water runoff. Although Birmingham's population shrunk by over 25 percent from 1980 to 2010, urbanization (highly-developed lands) within the City increased almost 20 percent over a similar time period, mainly concentrated interstate/highway corridors that extended out from the City's center (Rahman, 2014 and Trousdale, 2010). This corresponded to a direct decrease in forested or agriculture/light vegetation land cover.

After 2010, the City began to see a positive change in urban population statistics as economic shifts of the latter half of the 20^{th} century have taken root. This prompted revitalization of deteriorating and blighted areas, a growing movement towards reversing urban/suburban sprawl through downtown/in-town property redevelopment, as well as redevelopment and repurposing of abandoned industrial sites. Such efforts were evidenced in a boom in multi-family apartment construction in 2016 where 1,772 new downtown apartments were added, nearly three times as many constructed in 2015. At the writing of this manual, another 680 new multi-family units were projected to be available by the end of 2017 (Edgemon, 2017).

One result of the land use changes in Birmingham has been increased demand on Birmingham's aging storm water infrastructure system. Even after a City-led effort to unclog storm pipes and drains in June 2017, a July 24, 2017 rainfall event that dropped almost three inches of rain on Birmingham in one hour caused significant localized flooding due to, in part, poor runoff/drainage in urban areas. That same storm caused an increase in river stage of almost 7 feet for Fivemile Creek and over 12 feet for Village Creek where it intersects 24^{th} Street (**Figure 1-12)**, both located in downtown Birmingham (NWS, 2017).

Figure 1-12. Village Creek on July 24, 2017 and at Typical Stage *(Credit: Thomas A. Miller)*



Birmingham's almost 150 years of urbanization and related urban sprawl have also created water quality issues in numerous local streams whose watersheds fall within the City's municipal limits. Storm water impacts include measured water quality degradation, inclusion on

Alabama §303(d) listing of impaired water bodies, and the establishment of Total Maximum Daily Loads (TMDLs) for pollutants causing high-priority impairments.

An investigation of Village and Valley Creeks by the United States Geological Survey (USGS) in 2000 found that water quality and aquatic-community structure was degraded in those streams in comparison to streams flowing through less urbanized areas (**Figure 1-13**). Species richness and increased density of certain fish and invertebrates indicated that the degradation had occurred over an extended period of time. Decreased diversity and elevated concentrations of trace elements (e.g., cadmium, selenium, zinc, copper, mercury, and lead) and organic contaminants (e.g., organophosphate and organochlorine pesticides, polycyclic aromatic hydrocarbons, and polychlorinated biphenyls) in the water column, bed sediment, and fish tissues were indicative of the effects of urbanization. Industrial land use, in particular, was significantly correlated to elevated contaminant levels and the declining health of benthic-invertebrate communities (McPherson, et al., 2002).

Figure 1-13. Valley Creek at Lomb Ave. *(Source: blackwarriorriver.org)*

Since 2006, Portions of Village Creek have been listed on the Alabama §303(d) list for impaired water bodies for impairments related to the pesticide Dieldrin due to urban runoff/storm sewer sources. Village Creek from Locust Fork to Bayview Lake has been listed since 2012 for nutrient impairments due to industrial and municipal sources as well as urban runoff/storm sewer sources. Valley Creek from the Black Warrior River to the end of its embayment was added to the §303(d) list in 2016 for nutrient impairments from municipal sources (ADEM, 2016). More recently, Lake Purdy was placed on the 2018 §303(d) list (in draft at the writing of this manual) for mercury.

A TMDL quantifies the maximum amount of pollutant allowed to enter a waterbody to ensure that waterbody will meet and still continue to meet its water quality standards for a particular pollutant. Published TMDLs require reductions in pollutant loadings for the dischargers identified in the TMDL. The TMDL process is important for improving water quality because it links water quality standards and implementation of control actions designed to attain those standards (EPA, 2017). Noteworthy TMDLs for the City of Birmingham include:

- Shades Creek for turbidity, siltation, and habitat alteration (approved 11/1/2004);
- Village Creek for zinc, pH, and siltation (approved 8/24/2005);
- Village Creek (Bayview Lake) for siltation (approved 1/30/2006);
- Cahaba River for nutrients (approved 10/26/2006);
- Cahaba River for siltation and habitat alteration (approved 10/27/2013);
- Cahaba River for pathogens (E. coli; approved 11/21/2013); and
- Village Creek for pathogens (E. coli; approved 10/5/2015).

The storm water impacts detailed above, particularly the state §303(d) listings and federal TMDLs, clearly indicate a need for more focused and sustainable storm water management procedures and practices across the City of Birmingham.

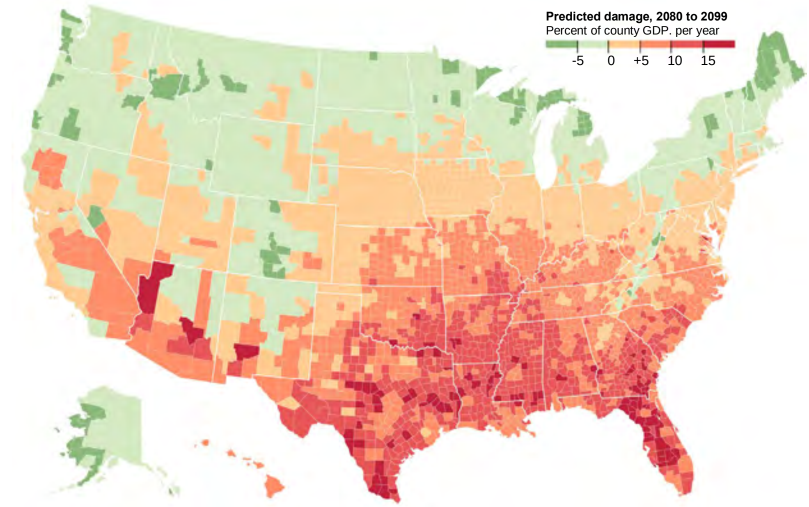
These procedures will help to reduce the impacts that urbanization has had on Birmingham's natural resources, and the identified practices, such as GIPs and LID, will aim to mimic nature through integrating storm water management into buildings and site developments.

1.3 Climate Adaptation and Storm Water

It is not uncommon today for storm water managers within local governments to feel the need to adapt their programs to respond to changing rainfall patterns and intensities. A number of scientific analyses indicate that a larger percentage of rainfall comes in the form of intense single-day events, and that the prevalence of these events has risen substantially since the 1980s (https://www.epa.gov/climate-indicators/climate-change-indicators-heavy-precipitation).

Whether a natural and cyclic meteorological phenomena or induced by man, global warming (also, climate change) is gaining the attention of local governments because of the potential impacts that such changing conditions may bring. A recent study analyzed the economic harm that can result from climate change, finding that communities in the southeast United States would experience significant damage from heat, floods, reduced productivity, etc. (Hsiang, et al., 2017). The results of the study predict that the Birmingham area could experience damages worth 5 to 10% of gross domestic product per year for every 1-degree Fahrenheit rise in global temperature (**Figure 1-14**).

Figure 1-14. Climate Change Damage Predictions *(Source: Hsaing et al, 2017)*



These predictions concern local governments because effective storm water management absolutely requires accurate planning for future conditions. For example, the design of storm water infrastructure is typically done for specific design storms (most commonly the 2- through 25-year frequency storms). These design storms are based on historical rainfall data. However, as stated by T. Moore of the Center for Watershed Protection, "One of the underlying assumptions of this design approach is that the rainfall probability distribution is static." A concern for this method is that the rainfall intensities and depths (and therefore volumes) of the design storms can increase in the range of five to fifteen percent as a result of changing climatic conditions. For minor storm water drainage systems that are already at capacity, this can lead to more frequent local flooding problems. The increased storm water and flooding will force planners and storm water specialists to develop strategies to deal with the increased volume and velocity of storm water.

1.4 Addressing Storm Water Impacts

The need for post-construction storm water management has evolved with urbanization. Land development and its potential impacts on property, human health and safety, and stream health led to the need for a formalized storm water management program at the local level.

1.4.1 The Evolution of Storm Water Management

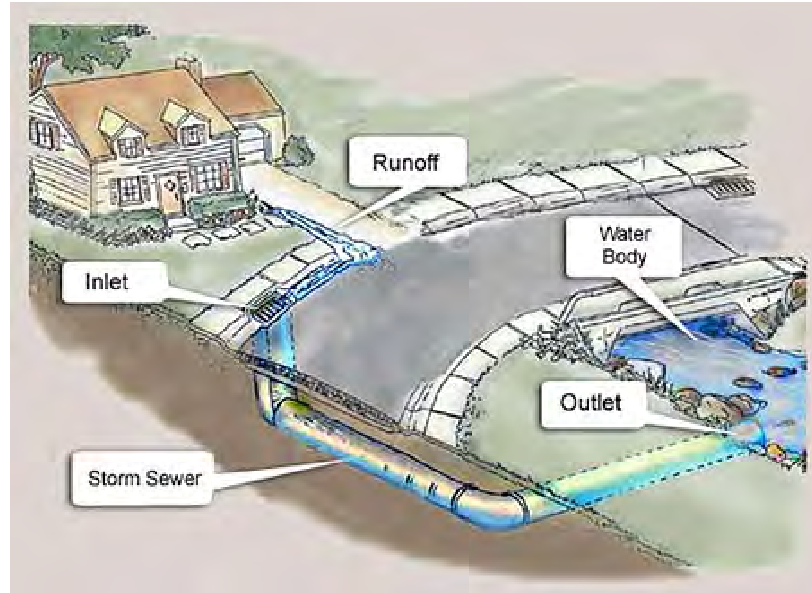
Prior to the late 1990s, most local post-construction storm water management programs focused almost exclusively on street and lot drainage and flood control (e.g., ditches, culverts, and detention ponds). This was the case in most communities in the United States where conveying storm water quickly and safely away from developed areas and roadways was the only storm water priority.

Over time, federal, state, and local government priorities have expanded with the recognition that storm water also contributes to the deterioration and loss of natural drainage ways, floodplains, vegetated areas along streams, and other water resources, all of which are valuable for drainage control and storm water quality management.

For most land developments, an engineered storm water drainage system is constructed to collect and carry storm water away from buildings, parking lots and roads. The storm water drainage system is comprised of streets, inlets, catch basins, gutters, pipes, and ditches (**Figure 1-15)**. On the property, the engineered system will carry the storm water directly to a stream or to the public storm water drainage system, which is managed and operated by the City of Birmingham.

The primary function of the public system is to reduce the potential for roadway and property flooding and safely carry storm water to local streams and other natural waterbodies.

Figure 1-15. Simplified Storm Water System *(Source: kentwa.gov)*

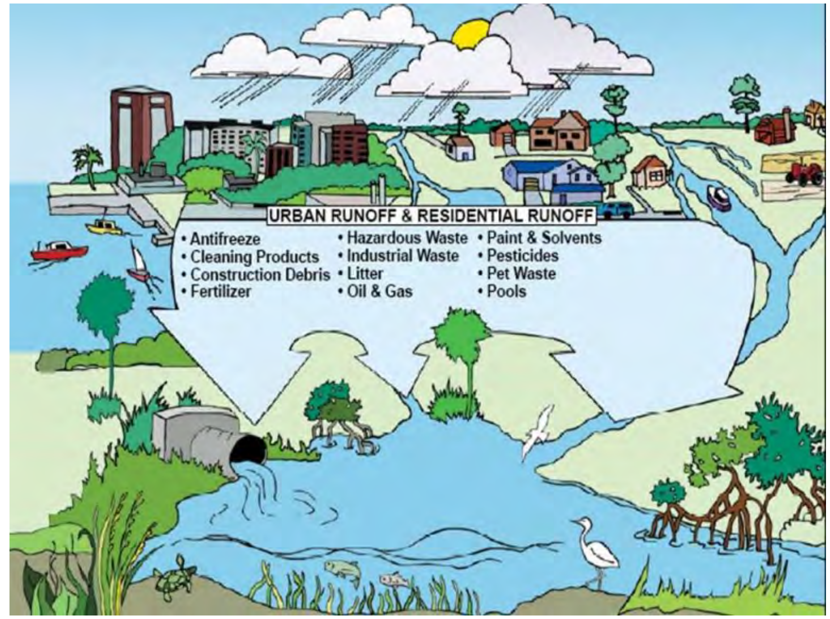


1.4.1.2 Drainage and Flood Control

Since the 1980s, the use of BMPs to retain or detain storm water on a developed property has been a standard approach for storm water management. Local governments across the country adopted ordinances requiring detention ponds, retention ponds, or other suitable types of storm water storage facilities. These storm water facilities were built with the singular purpose of "holding back" water to prevent drainage and flooding issues on a downstream property. Typically, these storm water facilities work by releasing the increased storm water at a slow rate for several days after a heavy rainfall. Storm water facilities built for this purpose are not very complex, generally consisting of a storage area (usually an excavated basin with an earthen embankment or berm), an outlet that regulates release rates for small storms, and an emergency outlet for large storms (either a large open pipe or concrete spillway over the berm) (**Figure 1-16**).

Figure 1-16. Typical Dry Detention Pond *(Source: City of Gadsden, AL)*

Figure 1-17. Common Storm Water Pollutants *(Source: Sarasota Bay Estuary Society)*



More information on the federal, state, and local drainage and flood control regulations relevant to land development in the City of Birmingham is provided in Chapter 2.

1.4.1.3 Storm Water Pollutant Control

In the 1990s and early 2000s, storm water practitioners became more aware of the fact that storm water can be a significant source of pollution in waterways. Unlike waste water from a house, industry, or business, storm water is not conveyed by underground pipes to a treatment plant where it is cleaned prior to its release to a natural waterway. Instead, most storm water runs off rooftops, roadways, pavement, and green spaces into the public storm water system of ditches and pipes, which carry it to a local waterbody (**Figure 1-17**).

Recognition that storm water is a major source of pollution prompted the United States Environmental Protection Agency (EPA) to initiate the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit program for local governments, under authorization by the United States Clean Water Act (33 U.S.C. §1251 et seq. (1972)). The NPDES-MS4 permit was rolled out in two phases. Phase I was established in the early 1990s and was aimed at large cities. The City of Birmingham, Jefferson County, Shelby County, and a number of the smaller communities immediately surrounding Birmingham have Phase I permits. Phase II of the program, promulgated in 2003, extended the NPDES-MS4 program to small to medium local governments. The Phase II NPDES-MS4 permit impacts many smaller jurisdictions in Alabama, such as Madison and Graysville. A map of regulated MS4s within the United States is presented in **Figure 1-18**.

Figure 1-18. 2009 Map of Regulated MS4s *(Source: epa.gov)*

The NPDES-MS4 program targets storm water pollution from local government operations and land development, and a NPDES-MS4 permit is a means for permitted local governments to achieve TMDL reduction targets when the government is identified as one of the dischargers to the subject stream. Among its many conditions, the permit requires that local governments create a post-construction storm water management program aimed at reducing or eliminating pollutant discharges from storm water that discharges from new land developments and redevelopments. Over the years, these "post-construction" requirements have become more prescriptive, focusing the permitted jurisdictions on target pollutants (often sediment and nutrients), a design rainfall amount, and specific pollution prevention and control approaches. Today, many NPDES-MS4 permits require some use (or encouragement) of LID and green infrastructure approaches to manage storm water, where feasible. Section 1.6 provides more information on the use of LID and GIPs in Birmingham.

1.4.2 Benefits of Addressing Storm Water Impacts

Proper storm water management and the implementation of sound practices to control storm water, especially LID/GIPs, can eliminate or alleviate many of the negative impacts discussed in the previous two sections of this chapter. In addition, there are many other benefits that can be realized by a community when a proactive approach is taken for storm water management and the implementation of LID/GIPs. These benefits are described below.

1.4.2.1 Community Development Benefits

- **Public Health –** Provision of greenspace and pedestrian connectivity within and between land developments allows for more opportunities for people to recreate and exercise, which can encourage people to be more physically active. Improved access to nature also contributes to improved overall health and wellness.

- **Beautification –** Installation of LID/GIPs creates additional greenspace in communities, which can improve the aesthetic qualities of urban and suburban areas.

- **Public Space –** Storm water controls can be designed to incorporate public gathering spaces. Smart design of controls allows them to provide multiple benefits.

- **Reduced Water Treatment Costs –** Like many communities, Birmingham's drinking water sources are local streams. Cleaner streams resulting from improved storm water management in developed areas can reduce the cost of water treatment.

- **Community Rating System (CRS) Credits** – The Federal Emergency Management Agency (FEMA) offers reductions in flood insurance premiums for private property owners in communities that have earned credit for flood resiliency activities, including storm water projects. Through the CRS, these premium reductions can be up to 45%.

1.4.2.2 Water Quantity Benefits

- **Disaster Preparedness, Resiliency, and Flood Control –** Communities that plan and implement projects to meet their storm water management needs are generally better able to convey storm water from flood events to detention facilities or receiving water bodies and away from sensitive properties and infrastructure.

- **Waterway Resiliency –** Utilization of LID storm water management practices that reduce storm water volumes and increase infiltration can reduce the intensity of flooding events while at the same time increasing base flows between storm events, which leads to healthier, more resilient waterways.

1.4.2.3 Water Quality Benefits

- **Water Supply / Source Water Resiliency and Protection –** Conservation of land, open space, and forest resources reduces the threat of contaminants being introduced to drinking water supplies.

- **Healthy Receiving Waters –** Effective storm water management practices will lead to reduced erosion and sedimentation in our waterways, as well as a reduction in nutrient loads that contribute to algae blooms and fish kills.

- **Public Health –** Preserving water quality and reducing pollution, through implementation of storm water projects and best practices, allow for safe recreation in receiving waters.

- **Recreation –** Rivers, lakes, and streams have long been destinations for recreation and enjoyment for many of the residents of and visitors to Jefferson and other nearby counties. Removal of debris and prevention of contamination improves recreational experiences for all water-goers.

1.4.2.4 Regulatory Benefits

- **Municipal Separate Storm Sewer Systems –** Storm water management and the implementation of best practices help the City of Birmingham comply with its NPDES-MS4 permit. More information on Birmingham's NPDES-MS4 permit is provided in Chapter 2 of this manual.

- **Total Maximum Daily Loads (TMDLs) –** The implementation of appropriate storm water management by the City and by private developers and land owners can lead to reductions in sediment, nutrients, and other storm water pollutants. Reduction of pollutant loadings to local streams and lakes is the objective of TMDLs. More information on TMDLs and how they influence local storm water management efforts is provided in Chapter 2 of this manual.

1.5 Post-Construction Storm Water Management in Birmingham

1.5.1 Brief History

Below is a brief discussion of the evolution of post-construction storm water management program in Birmingham.

Water Quantity: Birmingham's Department of Planning, Engineering & Permits was established by Ordinance (Code 1980, §7-3-41; Ord. No. 93-171, §1, 7-27-1993) in 1993. It was created to consolidate all functions of the formerly separate departments of Engineering and Urban Planning and any other such functions the Mayor or City Council might prescribe under the auspices of the City Engineer. Water quantity requirements are subject to the provision of the City's Engineering Guidelines, which were published by the Department of Planning, Engineering & Permits in March 2010 and updated again in December 2016. The document provides engineers with general information to assist them in the preparation of civil engineering plans that comply with City requirements and standard specifications for the construction of public works projects, subdivision regulations, and general engineering practices to control the release of the 25-year, 24-hour storms in Birmingham.

Water Quality: In 1972, the U.S. Congress passed significant amendments to the Federal Water Pollution Control Act, commonly referred to as the Clean Water Act. The Clean Water Act was later amended by Congress on February 4, 1987, by the Water Quality Act of 1987 to expand and implement the regulation of storm water point source discharges of urban runoff. EPA was tasked with the establishment of regulations to govern storm water discharges associated with industrial storm water discharges and the discharge from large MS4s. EPA delegated its authority to administer and enforce MS4 permits to ADEM. Unincorporated Jefferson County and the City of Birmingham were designated as large storm water systems.

On January 23, 1995 (Resolution No. 235-95), Jefferson County and the City of Birmingham entered into a joint agreement to implement permit compliance with the NPDES. The Storm Water Management Authority (SWMA) was later incorporated on March 3, 1997, pursuant to Act 95-775, codified at ALA Code §11-89C-1 et seq. (1975). The legislation and associated recodifications (Act 96-261; Act 97-2216) expressed the intent of the state legislature to assist the state in its implementation of the storm water laws and to supplement the authority of the governing bodies of all counties and municipalities in the state to enable them to supplement the storm water laws. The Act further stated that the legislature intended to make respective participation in a public corporation "inter-cooperative program optimal" (ALA Code §11-89C-1(d) (1975)). SWMA was incorporated to assist those permittees who chose to participate in the optional cooperative for the purpose of meeting their obligations under the NPDES permit and set forth in the Articles of Incorporation. Jefferson County and 23 municipalities, including Birmingham, became members of SWMA.

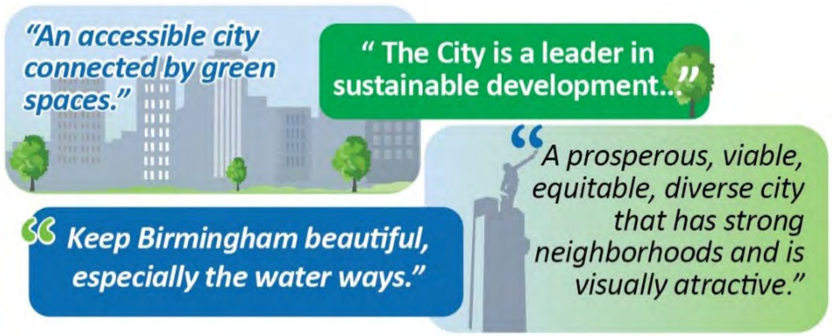
Effective October 1, 2008, Birmingham elected to withdraw from SWMA and to administer its own MS4 program by entering into an agreement on September 30, 2008, with Malcolm Pirnie, Inc. to develop the City's NPDES Stormwater Monitoring Program Plan. The monitoring plan was later modified and approved by ADEM on October 4, 2013. ADEM issued a notice to the City that coverage under the Birmingham Area MS4 NPDES Phase I Permit was administratively extended until the permit would either be reissued and/or until a separate individual permit was issued to the City. Birmingham's next NPDES MS4 Phase I Stormwater Permit (ALS000032) became effective on March 1, 2018.

1.5.2 Present Day

Birmingham's storm water management program has evolved beyond the limited storm water system (i.e., highway) maintenance performed in the 1950s and 60s. While traditional civil engineering practices for drainage management and flood control are still used, the impacts of storm water on local water resources, public and private properties, and in turn, the City's economic viability, are now better understood, prompting the need to expand beyond these traditional views of storm water as a nuisance byproduct of land development. When City government, citizens, and businesses view storm water as a valuable resource, non-traditional approaches for storm water management can be used to enhance the attractiveness of the City as a place to live and work and can support long-term sustainability and resiliency. Previously disconnected land development planning and site design concepts such as natural area conservation, natural drainageways, connected urban and suburban green spaces, redevelopment, and visual aesthetics, are increasingly connected to storm water management and water resources protection and, ultimately, to overall municipal well-being.

Such changes are happening now in Birmingham. The *City of Birmingham Comprehensive Plan* adopted in 2016 recognizes the ties between water resources protection, storm water and natural resources management, and Birmingham's future economic growth and sustainability. Personal vision statements put forward from stakeholders during the development of the plan's goals and strategies are very clear in this regard, as indicated in **Figure 1-19**.

Figure 1-19. Storm Water Relevant Stakeholder Vision Statements in the 2016 Birmingham Comprehensive Plan



The *City of Birmingham Comprehensive Plan*, includes several recommended strategies that are related to storm water management and water resources protection, with the overarching objective of enhancing the quality, prosperity, and attractiveness of the City as a place to live and work. These strategies are listed in **Table 1-1**.

In keeping with the strategies identified in the *City of Birmingham Comprehensive Plan*, present-day Birmingham uses a suite of tools to ensure that storm water is appropriately managed on developed land, both publicly and privately owned (see **Table 1-2**). These tools include ordinances and related support tools for the different types of stakeholders of local storm water management: developers; site designers (civil engineers and landscape architects); construction contractors; businesses and residential land owners; city staff; and even a myriad of businesses and professionals who can provide related support (e.g., plant nurseries, soil scientists, hydrologists, arborists, surveyors, landscape companies, etc.). Many of these tools were developed or modified in strong alignment with the strategies of the *City of Birmingham Comprehensive Plan*.

Table 1-1. Storm Water Relevant Comprehensive Plan Strategies

Goals
Support the creation of an interconnected green infrastructure network that includes natural areas for passive recreation, storm water management, and wildlife habitat.
Consider incentives for the conservation and enhancement of natural and urban forests.
Consider incentives for reinvestment in existing communities rather than "green fields", for new commercial residential, and institutional development.
Consider incentives for development patterns and site design methods that help protect water quality, sensitive environmental features, and wildlife habitat.
Continue support for non-city parks that provide recreational opportunities and access to nature.
Promote access and enjoyment of the City's major water features and open spaces.
Consider incentives for the preservation and protection of environmentally sensitive land.
Support clean-up and adaptive reuse of brownfields.
Consider incentives for, and encourage, development that protects the city's water resources.
Consider incentives for, and encourage the use of, natural drainage in storm water management systems where feasible.
Consider incentives for, and encourage the use of, conservation and low impact development techniques.
Support improvement of state water quality standards and encourage water efficiency standards and enforcement.
Support a rewrite and consolidation of development regulations to combine high-quality development with clear, user-friendly regulations and streamlined administration.

Table 1-2. Post-Construction Storm Water Management Tools

Tool/Document	Use or Purpose for Post Construction Storm Water Management
City of Birmingham Post Construction Storm Water Ordinance	Establishes the requirement for post-construction storm water management for all regulated development and redevelopment.
City of Birmingham Post Construction Storm Water Design Manual	Provides policies, procedures, guidance and support tools for the design and construction of post-construction storm water LID/GIPs/BMPs.
Birmingham Property Owner's Guide to Storm Water Management	Provides policies, procedures, guidance, and support tools for the protection, inspection and maintenance of post-construction storm water BMP.
Floodplain Zone Overlay	Regulates land development and buildings located in or near regulatory floodplains. Part of the Zoning Ordinance.
Birmingham Zoning Ordinance	Regulates property use and development, in terms of the placement, density, size, stories and height of buildings/structures, parking design, the size/use of open space, and landscaping. Closely aligned with Birmingham's Comprehensive Plan.
Birmingham Subdivision Regulations	Establishes standards of design for subdivisions, including roadways and associated infrastructure and natural resources.
Storm Water Master Plans	Studies of the existing and future hydrologic response to rainfall within a specific watershed. Used by the City to determine appropriate storm water management requirements.
City of Birmingham Comprehensive Plan	Overarching, City-wide strategies that guide future land use and land planning/design decisions. Used to guide smaller framework plans and City land development regulations.
Framework Plans	Future plan that influences policies regarding land use, new development, transportation, housing, parks, trails, open space, utilities, and economic development. Framework plans are specific to certain areas of the City.

1.6 The Use of LID and GIPs

1.6.1 Overview

Interest in and awareness of the need to better manage storm water in urban and suburban areas has increased in recent years. Current development patterns and traditional storm water management techniques have resulted in large amounts of impervious surfaces (e.g., roads, sidewalks and rooftops) across Birmingham. Conventional development approaches to storm water management often use practices to quickly and efficiently convey water away from developed areas. This results in large volumes of storm water, and therefore pollutants, flowing directly to streams and rivers.

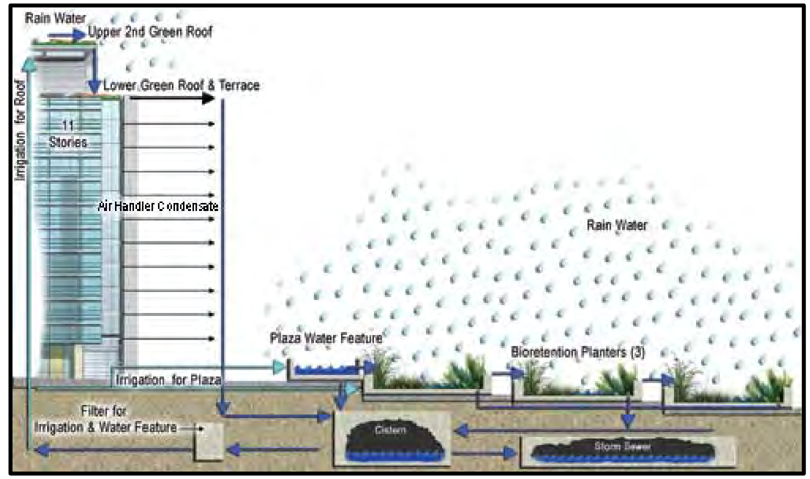
From a storm water perspective, LID is an approach to land development and redevelopment that works with nature to manage storm water as close to its sources as possible. LID employs principals such as preserving and re-creating natural landscape features and minimizing impervious surfaces to create functional and appealing site drainage systems that treat storm water as a resource rather than a waste product. For purposes of this manual, LID is considered a non-structural (i.e., natural, not constructed) approach to storm water management.

In contrast, GIPs refers to structural or intrinsic control practices that support the principles of LID and make use of volume-reducing designs and calculations to construct storm water facilities. GIPs (structural and intrinsic) utilize or mimic natural processes to infiltrate, evapotranspire, or reuse storm water on the property where it is generated. When LID and GIPs are used together, such as impervious area reduction and bioretention, they create an overall storm water management system that can help maintain more natural hydrologic conditions. Further connection of GIPs, such as a green roof and bioretention area, can keep greater volumes of storm water from routing to the storm water drainage system (**Figure 1-20**).

LID planning and GIP implementation have numerous benefits and advantages over conventional storm water management. The following benefits can be achieved by applying GIPs to new development, redevelopment, and capital improvement projects:

- **Provide volume control and pollutant removal.** Under traditional flood-focused storm water management, the importance of volume control from smaller storms and from the first flush of larger storms is overlooked. Reducing the amount of storm water runoff, however, is one of the most effective storm water pollution controls possible. LID planning and GIP implementation help reduce runoff volume and decrease the amount of storm water directly entering streams and storm water drainage systems. In addition to reducing runoff volumes, individual GIPs can help address specific pollutant removal efficiencies through settling, filtration, adsorption, and biological uptake. By doing so, GIPs can help improve the receiving water's aquatic and terrestrial wildlife habitat and enhance recreational uses.

Figure 1-20. Example of Combined Green Roof / Bioretention System *(Source: landscapeonline.com)*



- **Recharge groundwater and stream base flows.** Development tends to increase imperviousness, leading to increased direct storm water runoff and reduced rainfall infiltration. Groundwater helps feed lakes and streams, and significant reductions or loss of groundwater recharge can reduce base flow in receiving waters, negatively impacting biological habitat and recreational opportunities. Many GIPs listed in this manual infiltrate runoff, thus promoting ground water recharge.

- **Restore and protect stream channels.** Channel erosion, on average, is estimated to account for most of the sediment load in urban watersheds and is a significant contributor to TSS issues in Birmingham, according to ADEM (2005). LID planning and GIP implementation can help protect or reduce stream channel degradation from accelerated erosion and sedimentation during and immediately after storm events by reducing and capturing storm water volume and lowering storm water peaks. By protecting stream channels, stream and riparian ecosystems have the potential to be improved and restored.

- **Provide additional environmental benefits.** LID planning and GIP implementation provide additional benefits such as improved aesthetics using attractive landscaping features (trees, shrubs, and flowering plants) that can increase property values. Other benefits include increased public awareness of storm water management and water quality issues since practices are dispersed throughout a site and are typically more visible. GIPs such as green roofs, bioretention, and urban trees can help to mitigate the urban heat island effect and green roofs can also decrease the energy required to heat and cool buildings.

1.6.2 Multifunctional Uses for LID/GIPs

As a result of the need for both drainage/flood control and storm water pollution control, local governments typically have regulations that address both issues. Site designers must now find ways to manage the increased volume, velocity, intensity, and quality of storm water in one storm water control facility or via multiple facilities. In turn, GIPs can provide new ways to maximize the functionality of property spaces by combining storm water management functions with other property needs such as landscaping, extra parking, or even a building roof (**Figure 1-21**).

1.6.3 Rationale for LID/GIP Use in Birmingham

A growing understanding of the negative effects of increased storm water is leading to new and innovative ways to handle it, many of which imitate natural processes of infiltrating water into the soil. With its aging infrastructure, drainage and flooding issues and, now, the NPDES-MS4 permit, Birmingham has a more comprehensive storm water charge than ever before, which includes both storm water quantity <u>and</u> quality. Both target areas can be addressed, at least in part, through the use of LID and GIPs. As a result, this manual emphasizes LID planning and GIP implementation as a priority on development and redevelopment sites within the City. LID practices and GIPs are showing up in developments and parks (**Figure 1-22**) and are considered more readily acceptable by local site designers and developers.

Figure 1-21. Green Roof in Benjamin Russell Hospital for Children in Birmingham, AL *(Source: Macknally Land Design)*

Figure 1-22. Bio-filtration Wetlands and Native Vegetation in Railroad Park, Birmingham, AL *(Source: alabamaasla.com)*

Careful consideration of storm water management is critical for Birmingham officials and staff, businesses, homeowners, developers, and land development designers; however, it is rare that these groups have an opportunity to work together in planning for Birmingham's future development and redevelopment. LID is an interdisciplinary approach to storm water management planning that, when coupled with GIP implementation and maintenance, can result in improved storm water quality, improved health of local streams and rivers, and reduced flooding. LID planning and GIPs can also provide more attractive landscapes, wildlife habitat benefits, and improved quality of life for our citizens. The wide variety of stakeholder benefits that can stem from the use of LID/GIP use in Birmingham are listed below.

City of Birmingham Benefits

- Effective tool for storm water management
- Balances sustainability and economic growth needs with environmental protection
- Aligns with Birmingham's Comprehensive Plan and the American Society of Civil Engineers' recommendations
- Reduces the City's infrastructure and utility maintenance costs (streets, curbs, gutters, sidewalks, storm drainage system)
- Decreases flooding risks for small storms
- Creates attractive and multifunctional public spaces
- Encourages private sector participation in sustainable storm water infrastructure at residential, commercial, and industrial properties
- Supports storm water pollution reduction requirements of the NPDES-MS4 permit

Land Developer Benefits

- Reduces land clearing and grading costs
- May reduce infrastructure costs (streets, curbs, gutters, sidewalks)
- May reduce construction, materials, and maintenance costs
- Reduces storm water management costs
- May reduce City permitting costs and increase lot yields
- Increases lot and community marketability

Property Owner Benefits

- May reduce maintenance costs
- Can increase a property's landscape/hardscape aesthetic
- Can provide functional green spaces for recreation and enjoyment of the natural environment
- Increases property marketability

Environmental Benefits

- Preserves integrity of ecological and biological systems
- Protects site and regional water quality by reducing sediment, nutrients, and pollutant loads to local waterways
- Reduces impacts to terrestrial and aquatic plants and animals
- Preserves trees and natural vegetation
- Mitigates the heat island effect and reduces energy use

1.6.4 LID/GIP Emphasis in Birmingham Standards

The overall goal of LID planning and GIP implementation is to reduce storm water runoff volume, treat pollutant loads close to the source where they are generated, and make use of natural storm water management processes where feasible. These goals are best accomplished with early consideration of LID in the site planning process and through the direction of storm water towards small-scale GIPs that are dispersed throughout the site (**Figure 1-23**). GIPs should be carefully selected based on the site's topographic and climatic conditions.

Figure 1-23. Example of LID and GIPs at Railroad Park: Urban Trees and Water Quality Swale *(Credit: Siera Jann)*

The use of LID and GIPs is the preferred approach for storm water management at land developments in Birmingham. As such, the storm water management tools presented previously in Table 1-2 support a site designer's use of LID and GIPs as much as possible. This manual presents an introduction to LID planning and GIP implementation, which are characterized by their ability to reduce storm water runoff volume, and thus reduce pollutants, through the use of infiltration, evapotranspiration, and/or reuse of storm water. It describes how LID should be considered in advance of land design, how GIPs should be selected, when GIPs are not appropriate or may not be feasible and contains a series of focused and concise fact sheets for each type of GIP.

Birmingham's approach for complying with NPDES-MS4 permit requirements through strong encouragement of LID/GIPs uses a primary design method called the Annual Runoff Reduction Method (also called the Rv Method). The method, described in detail in Chapter 3, was developed to allow local governments and site designers to "measure" how a post-construction site design results in runoff that mimics pre-construction hydrology to the maximum extent practicable using LID planning and GIP implementation. The Rv Method includes recognition of circumstances when LID and GIPs will not be feasible on a land development because of physical, hydrologic, or financial constraints. The City's policies (see Chapter 2) allow the use of an alternate approach for pollutant removal from storm water is then used to ensure that post-construction storm water quality management is still performed at the land development.

Developers and site designers who work outside of Alabama are already noticing that LID and GIPs are increasing in popularity in the south east United States and across the nation. As a result, there are a myriad of resources beyond this manual that can be consulted for site design and land use planning ideas. Links for several key external resources are below. Site designers are also encouraged to look for information from technical associations such as the American Society of Civil Engineers and American Society of Landscape Architects.

Alabama Low Impact Development Handbook:
www.adem.state.al.us/programs/water/waterforms/LIDHandbook.pdf

EPA LID website: www.epa.gov/nps/urban-runoff-low-impact-development

EPA GIP website: www.epa.gov/green-infrastructure

1.6.5 When LID/GIP is Not Feasible

While the use of LID and GIPs is the preferred approach for storm water management at land developments in Birmingham, it is not the only approach. The City recognizes that LID and GIPs will not be feasible for every new land development or redevelopment for a variety of reasons ranging from physical to financial. Site designers can opt to comply with storm water quality requirements using the more traditional approach of pollutant removal. Similar to many local governments across the United States, Birmingham has opted to use TSS as the pollutant targeted for removal. TSS is often used as an indicator or measure of the sediment in water.

In contrast to an LID/GIP approach that prevents pollutants from entering storm water, TSS removal protects stream/lake water quality by treating storm water that is already polluted with sediments, as contaminants such as metals may adsorb to sediment particles. A variety of accepted TSS removal practices are included in this manual and include extended detention, filtration, or mechanical separation (e.g., centrifugal force) to improve storm water quality. Like the LID/GIP approach, TSS removal is regarded as a feasible, protective standard for storm water quality management.

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Chapter 2. Administrative Policies, Processes, and Guidance

By emphasizing the minimization of runoff volumes and requiring the selection, design, and installation of appropriate and effective storm water controls, Birmingham's design and construction process can improve the long-term sustainability of privately-owned infrastructure.

Storm Water Design, Planning and Post-Construction Permit Process

Runoff Reduction and Pollutant Removal Capability

The City makes every effort to consistently meet clean water standards.

A pre-concept sketch and conference optimize the future on-site storm water system design and plan review process.

Plan Review Assistance

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2.1 Introduction

2.1.1 Purpose

The purpose of this chapter is to define Birmingham's regulatory process for storm water related site planning, design, and construction. This process was developed to support the site designer in addressing the items above. Also, included in this chapter are brief descriptions of the local, state, and federal regulations and initiatives that influence storm water management planning for land developments in Birmingham.

2.1.2 Key Questions of the Design Process

Effective storm water management on a land development requires a site designer's forethought and sound knowledge of: the regulations, plans, and other initiatives that regulate or influence storm water system design; the hydrology and hydraulics of the land development site; and the site's potential storm water impacts on downstream properties. It also requires consideration of the needs of all relevant stakeholders: the developer (and sometimes investor) with vision for the development and the financial stake in its success; the site designer tasked with carrying out the developer's vision in accordance with applicable codes and ordinances; the City who must provide for public safety and, thus, determine whether the design/construction meets the aforementioned codes and ordinances; and future property owners that will be responsible for the inspection and maintenance of on-site storm water systems after they are constructed. To meet the needs of all stakeholders, several questions must be considered and answered including the grading requirements, impervious surface layout, and storm water design for a land development begin to take shape.

- How can the site's storm water drainage system be designed to most effectively meet Birmingham's storm water management performance standards (see Chapter 3) without negatively impacting the overall vision and economic model of the developer/investor?

- What are the opportunities for utilizing Low Impact Development (LID) and/or Green Infrastructure Practices (GIP)? How can they be cost effective for the developer while also benefitting the development and/or owner *after* construction?

- Are there (or will there be) physical, environmental, or land use constraints on the site that either preclude the use of certain storm water management approaches (such as infiltration) or that require special design considerations to protect environmentally impaired water bodies or threatened or endangered species?

- What structural storm water management practices are most practicable for the future land use, given that practices must be routinely inspected and maintained?

The process of storm water management planning and design described in the following sections constitutes the administrative procedures and tools that must be followed during the design and construction of on-site storm water systems. This process helps developers and site designers answer the above questions because it is aligned with the *City of Birmingham Post Construction Storm Water Ordinance* and with the policies established in Chapter 3 and facilitates consideration of the storm water design principles and methods presented in Chapter 4. For property owners, the process provides a clear starting point for long-term maintenance, so the property owner can be assured they are taking ownership of a storm water system that is properly constructed and operating in good working condition once construction is complete. Finally, the process provides the City with a reasonable level of consistency and uniformity in site plan preparation and approval, ensures compliance with State of Alabama storm water permit requirements, and sets the stage for the City's administration of long-term storm water system maintenance requirements.

Toward these ends, Birmingham uses a comprehensive site planning, design, and construction process that involves the following key components:

1. A pre-concept planning review of existing site hydrology that facilitates consideration of cost-saving LID and other storm water management techniques and a mutual understanding of site constraints for the developer, site designers, and City.
2. A storm water design plan and permit process that provides consistent and readable design plans to City staff, provides clear direction to the site designer for plan preparation, and results in a focused, efficient plan approval process.
3. A storm water record drawing approval process that documents the constructed storm water system and ensures its proper functional condition prior to takeover by a subsequent property owner.

2.2 The Storm Water Permitting Process

2.2.1 Terminology

The following terminology terms are used in the sections that follow.

- The "**Director**" is the Director of the Department of Planning, Engineering & Permits or his/her authorized representative.
- The "**department**" is the Department of Planning, Engineering & Permits.

2.2.2 Overview

Figure 2-1 presents the general sequence of activities to obtain, and begin work under, a Post Construction Storm Water Permit for land developments that are subject to the *City of Birmingham Post Construction Storm Water Ordinance*. The figure largely shows the process for storm water planning and design. The process is continued in **Figure 2-2**, which shows the general steps for construction and permit termination.

Both figures include regulatory and non-regulatory events, from initial consideration of a property by the developer to the point that a certificate of occupancy is obtained, the permit is terminated, and bonds are released. Note that the figures are general representations and do not show the more detailed steps of specific inspections or enforcement actions during construction. As well, different property conditions or situations can result in changes to the process shown in the figures.

Sections 2.3, 2.4, and 2.5 that follow the figures present the Post Construction Storm Water Permit and its associated required plans and include relevant policies.

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Figure 2-1. Post Construction SW Permit Approval Process

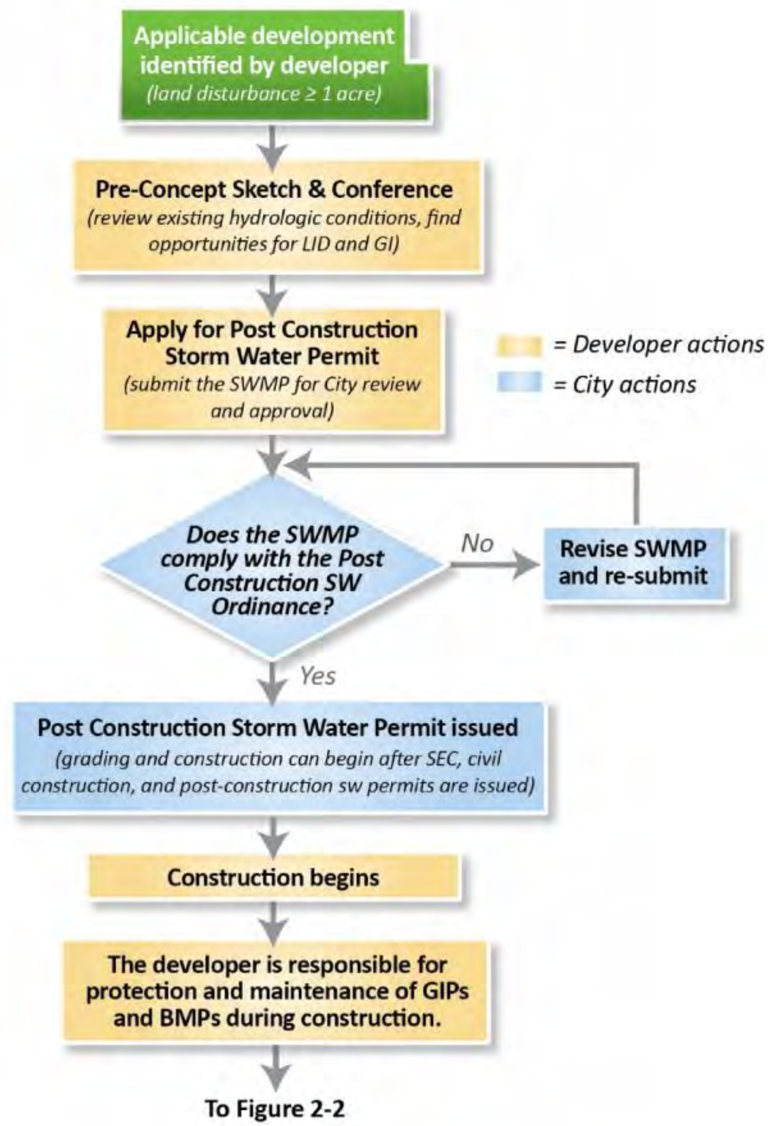
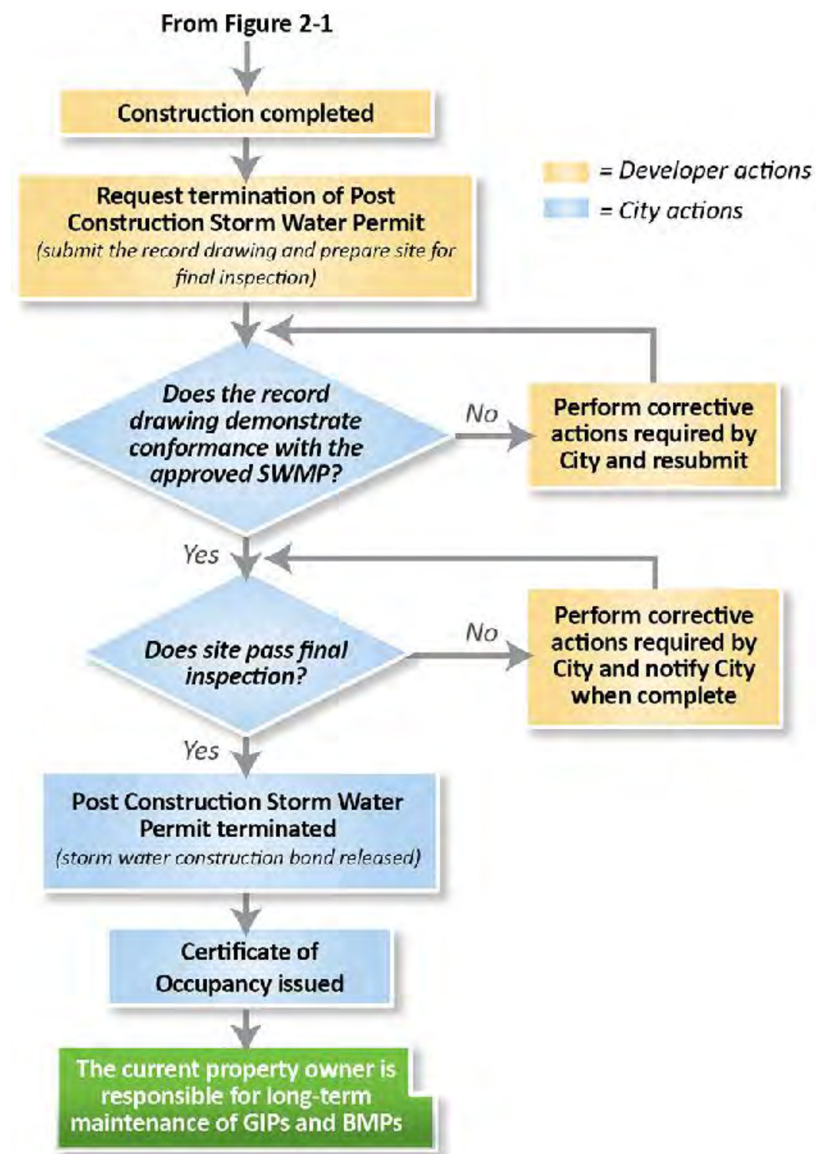


Figure 2-2. Post Construction SW Permit Termination Process



2.3 The Pre-Concept Sketch and Conference

2.3.1 Background and Objectives

The *City of Birmingham Post Construction Storm Water Ordinance* requires the submittal of the pre-concept sketch and attendance at the pre-concept conference. This process does not require design calculations or analyses nor does it result in a plan approval. Rather, the process is used to characterize the hydrologic aspects of the property in its existing condition. The objectives of the process are to optimize the future on-site storm water system design and plan review process and identify opportunities for natural storm water management using LID. The intent of the process is to evaluate information about site hydrology (and potentially other environmental issues) in a collaborative way that can ultimately be beneficial to the overall project.

Preparation of a pre-concept sketch will include the identification and location of features of the development that are important for effective storm water management. These features include, but are not limited to, land cover, hydrologic soil groups, streams, steep slopes, sinkholes, floodplains, bedrock, and existing on-site and adjacent manmade features or storm water systems. Environmentally impaired waters and environmentally-sensitive areas (e.g., due to the presence of threatened or endangered species) will also be included.

The pre-concept sketch is required early in the site planning process, ideally before a site design is created for a future land development and definitely before clearing, grading, and construction begin. Early preparation is advantageous for several reasons:

- An early understanding of the site's hydrology can reveal potential opportunities to naturally reduce storm water volumes using non-structural LID techniques and structural GIPs. In turn, natural reduction of storm water volumes can potentially decrease the size, cost, and maintenance of the future on-site storm water system.
- A pre-concept sketch can be useful for site layout planning by allowing the site designer to optimize the location of impervious areas (buildings and pavement), GIPs, and Best Management Practices (BMPs) based on the site's natural vegetation and soils. This early planning can significantly increase the development's ability to meet storm water control standards using less costly and more natural approaches.
- A pre-concept sketch allows both the site designer and city plan reviewers to identify and understand very early in the site planning process any limitations to LID and GIPs that may exist. This early recognition can result in the avoidance of design analyses (and associated costs) for unfeasible storm water practices and can allow a more efficient design and plan review experience.
- A pre-concept sketch and conference can allow the site designer and city plan reviewers to identify the potential need for additional data or information to support the eventual design, thus putting everyone "on the same page" and facilitating a more efficient design and plan review process.

2.3.2 Roles and Responsibilities

2.3.2.1 Design Team

The design of any private development lies with the design team (developer, engineer, architect, landscape architect, etc.). As such, the design team is responsible for:

- Preparing the pre-concept sketch and submitting it to the department;
- Scheduling the pre-concept conference;
- Attending the pre-concept conference; and
- Gaining the required signature from department staff attending the pre-concept conference (on the pre-concept checklist).

2.3.2.2 Department of Planning, Engineering & Permits

Pre-design sketches are prepared by the design team to characterize the existing site hydrology and should be done well in advance of site layout and design. The sketch is a gathering of available information regarding the existing site hydrology and engineering design, analysis, and tests are not required at this early stage in site planning. As well, design approval is not part of the pre-concept process. Therefore, the department's role at the pre-concept stage is non-regulatory and largely advisory. While department staff may collaborate with the design team by suggesting storm water management approaches that could be beneficial to the proposed project, they do not have the authority to impose site layout and design *preferences* that are not already part of City code.

Birmingham's Chief Engineer – Watersheds will be the department's primary attendee at the meeting. Other department staff, such as the floodplain administrator, city engineer, and site inspector(s), may attend depending on specific conditions on the site or questions that the developer's design team may have.

The department's responsibilities are:

- Reviewing the pre-concept sketch;
- Facilitating the pre-concept conference;
- Listening to the site design teams initial vision for storm water management;
- Advising the design team on storm water management and permitting issues within the bounds of City code; and
- Signing the pre-concept checklist as proof of the conference occurring.

2.3.3 Policies

The following policies shall apply to the pre-concept sketch and the pre-concept conference, pursuant to the *City of Birmingham Post Construction Storm Water Ordinance*.

1. **Submittal timeframe.** The pre-concept sketch will be submitted to the department as a stand-alone document at least 3 to 5 days prior to the pre-concept conference.
2. **Professional qualifications not necessary.** Professional licensing in the State of Alabama is not required for preparation of a pre-concept sketch. (Ideally, however, the sketch should be prepared by the person who will be designing the site layout, such as an engineer, landscape architect, or architect competent in civil and site design.)
3. **Required use of the pre-concept sketch checklist.** The applicant shall prepare a pre-concept sketch in accordance with the checklist provided in Appendix B of this manual. The checklist provides a complete inventory of the desired contents of the sketch. As many of the checklist elements as possible should be provided, based on the availability of data. Those elements that are not applicable to the project or not available must be indicated as such on the checklist. Proper use of the checklists will facilitate a more meaningful and efficient pre-concept conference.

   It is recognized that some checklist elements will be easy to gather by visual inspection or using maps available to the general public (e.g., USGS Quadrangles, NRCS soil surveys, publicly available aerial photography, etc.), while the provision of other requested elements may require engineering field tests or environmental surveys. While the department welcomes and encourages the collection of all the elements on the checklist in order to develop a well-informed storm water management vision for the site, engineering or environmental tests or surveys are not required by the City for inclusion with a pre-concept sketch. Checklist elements that would require such tests or surveys can be marked as "No Data" if the tests have not been previously performed.

   Note that engineering or environmental tests, surveys, and related analyses may be required later in the land development process to obtain a Post Construction Storm Water Permit or other local permit.

4. **Map scale requirement.** All maps provided with a pre-concept sketch must be to scale with a scale no larger than 1:50.

5. **Scheduling the pre-concept conference.** It is the responsibility of the developer (or his/her designee) to schedule and attend the conference and to invite and coordinate with any non-City participants that he/she wishes to attend. The developer's entire site design team is encouraged to attend. When requesting the meeting, the developer should also identify specific questions, issues, or needs about the site so that the appropriate department staff can attend the meeting.

6. **No approvals at pre-concept conference.** The department will not accept, consider, examine, or approve any permit applications or design plans at the pre-design conference.

7. **Pre-concept process required to gain permit.** Applications for a Post Construction Storm Water Permit will not be considered if a pre-concept conference has not occurred. The conference is documented by the signature of the department attendee on the pre-concept sketch checklist that is submitted with the sketch (see Appendix B).

2.4 The Post Construction Storm Water Permit

2.4.1 Background

Any developer or property owner of a new development or redevelopment that is subject to the *City of Birmingham Post Construction Storm Water Ordinance* must obtain a Post Construction Storm Water Permit prior to the commencement of land disturbance activities. In general, this means that the permit is applicable to land developments that will result in one acre or more of land disturbance.

The Post Construction Storm Water Permit facilitates the design plan review, construction inspections, and record drawing review associated with a land development's storm water management system. Relative to these activities, the objectives of the permit are to:

- Prompt the plan review and construction process for a proposed land development;
- Authorize the developer to commence with construction of the approved design for the on-site storm water management system, including GIPs and BMPs for total suspended solids (TSS) removal and storm water peak flow control (e.g., detention ponds);
- Ensure that the storm water management system is constructed in accordance with the City-approved design;
- Ensure that the storm water management system is fully functional and will operate properly upon completion of land-development construction; and
- Register the land development in the City's post-construction storm water maintenance program.

The Post Construction Storm Water Permit is administered by the department. Permit application and submittal is handled through the City's standard permit office/counter. The application and issuance of the Post Construction Storm Water Permit will occur within the department's standard process used for all other land development-related permits.

The lifespan of a Post Construction Storm Water Permit for a development begins upon issuance of the permit and ends when the record drawing is approved and the land development passes the final storm water system operation inspection. Plan approvals and the inspection are performed by the department. Throughout this time, the applicant is considered to have an "active" permit. Construction of the on-site storm water system is allowed, in accordance with the approved plan and the *City of Birmingham Post Construction Storm Water Ordinance*, and the permit holder is responsible for the protection, inspection, and maintenance of the system in keeping with the ordinance. During this period, construction inspections will occur as the construction project progresses. When construction is complete, the permit holder must close the Post Construction Storm Water Permit.

2.4.2 Policies for Obtaining a Permit

The following policies shall apply to the Post Construction Storm Water Permit, pursuant to the *City of Birmingham Post Construction Storm Water Ordinance*.

1. **Permit application timeframe.** It is recommended that applications for a Post Construction Storm Water Permit should be made at least 8 weeks after the pre-concept conference. A proposed land development may be placed on hold without consideration by the department until the requisite time has elapsed, if warranted.

2. **Pre-concept conference certification required.** The department will not approve any application for a Post Construction Storm Water Permit without a completed pre-concept conference certification.

3. **Complete application required.** Person(s) responsible for land developments that are not exempt from the requirement for a Post Construction Storm Water Permit shall submit a complete permit application to the department. Review of the application will occur only after all the required information is submitted and the required fee has been paid. Requisite information is listed below.

   a. Post Construction Storm Water Permit application cover sheet (obtained from the department)

   b. Signed pre-concept conference certification

   c. Executed maintenance agreement

   d. Three complete hardcopy sets of the SWMP (see Section 2.5.1)

   e. Three complete hardcopy sets of the Soil Erosion and Sediment Control plan, if not already submitted to obtain a Soil Erosion and Sediment Control Permit

   f. Storm water design certification (see Appendix B)

   g. Soil erosion and sediment control certification (if not already submitted with the Soil Erosion and Sediment Control Plan)

   h. Surface water drainage certification (if not already submitted with Soil Erosion and Sediment Control Plan)

   i. One digital (*.PDF) copy of all the above

4. **Permit issuance.** The Post Construction Storm Water Permit will be issued upon confirmation by the department that the SWMP and designs shown therein comply with the *City of Birmingham Post Construction Storm Water Ordinance*, the *City of Birmingham Post Construction Storm Water Design Manual*, and other applicable regulations.

5. **Permit duration.** The Post Construction Storm Water Permit expires 5 years after the date of issuance. The applicant must request permit closure at the end of construction, in accordance with this manual (see Section 2.4.3). See the *City of Birmingham Post Construction Storm Water Ordinance* for additional provisions regarding permit expiration, suspension, revocation, or termination.

2.4.3 Policies for Permit Termination

The *City of Birmingham Post Construction Storm Water Ordinance* establishes the conditions under which a permit can be terminated (i.e., City approval of the record drawing approval and final inspection). Permit termination should be requested only after all elements of the storm water system are fully constructed (including all vegetated areas associated with GIPs and BMPs), all pervious areas on the land development are permanently stabilized, the storm water management system has been cleaned and is free of sediment, debris, and other potential pollutants, and a storm water record drawing is ready for submittal to the department.

The following policies shall apply to the Post Construction Storm Water Permit, pursuant to the *City of Birmingham Post Construction Storm Water Ordinance*.

1. **Requesting permit termination.** Person(s) desiring to terminate a Post Construction Storm Water Permit for constructed land developments shall submit a complete record drawing to the department. Review of the record drawing will occur only after all the required information, fully completed in accordance with this manual, is submitted. Requisite information is listed below.

   a. Three complete hardcopy sets of the storm water record drawing (see Section 2.5.2)

   b. Storm water as-built certification (see Appendix B)

   c. One digital (*.PDF) copy of all the above

   Person(s) desiring to terminate a Post Construction Storm Water Permit for a land development that was partly or not constructed shall submit a letter that includes following information:

   a. The permit number;

   b. The permittees name and contact information (provide also the owner's name and contact information, if different);

   c. An explanation of why construction was not performed or completed;

   d. A detailed explanation of what activities were performed on site related to the approved SWMP and the approved SEC plan; and,

   e. A detailed description of the current condition of the site.

   If the land development was partly constructed, the owner(s) shall consult the department to determine the plan(s) that must be submitted for storm water compliance.

2. **Storm water system operation inspection required.** The receipt of a record drawing indicates to the department that the land development is ready for a final inspection of storm water system operation. After the record drawing is approved, department staff will visually inspect the development's storm water drainage system. To pass inspection, the site must exhibit.

   a. The system, including GIPs and BMPs, must be fully constructed, undamaged, and free of construction sediment, debris, and other items that can cause blockages or reduce system capacity/discharges.

   b. Sediment must be removed from post-construction BMPs that were converted from a sediment trap or basin used to capture construction sediment. The BMP must have full storage capacity.

   c. Permanent vegetation must already be installed in all vegetated areas, including in vegetated GIPs and BMPs. Vegetation must appear healthy and growing. Areas of bare soil cannot be present.

   d. Construction and landscape materials stockpiles are not present in the drainage areas to GIPs and BMPs.

   e. None of the prohibited conditions for GIPs and BMPs, as established in the *City of Birmingham Post Construction Storm Water Ordinance*, can be present.

3. **When corrective actions are required.**

   a. Any of the following circumstances shall result in the requirement(s) for corrective action(s), either to modify a record drawing and/or correct an issue with the on-site storm water system. The applicant is responsible for making all corrective actions.

i. A storm water record drawing indicates that the on-site storm water system has not been constructed in accordance with an approved SWMP or that the on-site storm water system does not comply with the storm water performance standards required for the land development.

ii. The storm water system operation inspection indicates that the on-site storm water system has not been constructed in accordance with an approved SWMP.

iii. The storm water system operation inspection indicates that the on-site storm water drainage system or areas of the development require cleaning, maintenance, or repair to ensure that the system and its GIPs and BMPs are is fully functional, clean of sediment, debris, trash and other items, and working in a proper operating condition.

iv. The storm water system operation inspection indicates that the pervious areas of the land development are not fully vegetated or sufficiently stabilized to prevent soil erosion and control sediment discharges into the on-site storm water system or offsite.

v. Other conditions that can affect the operation or function of the storm water drainage system as identified in the record drawing or storm water system operational inspection.

b. When required, corrections to the storm water record drawing can be resubmitted directly to the department.

c. When corrective actions result in alteration, repair, or maintenance to the on-site storm water system, the applicant shall indicate completion of the corrective action(s) by submitting another request for permit closure in accordance with Policy 1 immediately above. It is not necessary to resubmit the storm water record drawing if they were not modified. A follow-up inspection by the department may be performed to confirm satisfactory results.

2.5 Storm Water Permit Plans

2.5.1 The Storm Water Management Plan (SWMP)

The SWMP is the engineering plan that describes the site designer's approach for achieving the storm water performance standards, established in Chapter 3 of this manual, on a proposed land development. In general, the plan describes how the hydrologic characteristics of the site will change as a result of the proposed land development, how the appropriate performance standards for storm water will be achieved, and presents the detailed designs for any GIPs, BMPs, and stream buffers that will be permanently located on-site.

A Post Construction Storm Water Permit cannot be obtained without approval of the SWMP by the department.

2.5.2 The Storm Water Record Drawing

The storm water record drawing documents the as-constructed condition of the on-site storm water system. Record drawings may be used by the City or property owner to guide the owner's routine or remedial maintenance of the storm water GIPs, BMPs, or drainage system on the property. These drawings are also used by City staff to update the watershed management models that are maintained by Birmingham's Storm Water Department to gauge watershed response to land development and keep policies abreast of watershed management needs.

For permit closure and the start of long-term maintenance, the record drawing serves two purposes: 1) to check construction conformance with the approved storm water design; and 2) to establish the location, type, extent, and construction of GIPs and BMPs for registration in the

City's post-construction storm water maintenance program. The record drawing is compared to the approved SWMP as differences between the two plans could indicate that the constructed on-site storm water system does not meet the required storm water performance standards.

A Post Construction Storm Water Permit cannot be closed without approval of the storm water record drawing by the department.

2.5.3 General Plan Policies

The following policies shall apply to the SWMP and the storm water record drawing, unless one or the other is explicitly specified in the policy. Both are referred to as "plans" in these policies. These policies are established pursuant to the *City of Birmingham Post Construction Storm Water Ordinance*.

1. **Requirement for complete plans.** Only complete plans will be accepted for review by the department. Omission of any required elements of a plan, unless not applicable, renders the plan incomplete, delaying plan review and permit issuance or termination. The applicant will be advised of plan deficiency(s) and requested to correct them before resubmitting the plan.
2. **Required use of the plan checklist.** The applicant shall prepare the plan in accordance with the applicable checklist provided in Appendix B of this manual. The submitted plan shall, at a minimum, include all the elements listed in the checklist except for those elements that are not applicable to the project, which must be indicated on the checklist as "not applicable." A fully completed checklist must be included with the plan at the time it is submitted for review. Proper use of the checklists will ensure submittal of complete plans and will facilitate efficient plan review processes.
3. **Proof of other permits required.** It is the responsibility of the applicant to thoroughly review, understand, and adhere to all applicable local, state, and federal laws and regulations with regards to site development and property regulations when submitting the SWMP. Copies of all applicable state and federal permits must be provided to as part of the plan, as is indicated in the plan checklist.
4. **Specification of easement, GIP, and BMP features.** The locations and boundaries of easements, GIPs, and BMPs shall be clearly identified on all maps submitted with plans and may be required to be shown on a legal subdivision plat prepared by an Alabama-registered Professional Land Surveyor. GIPs and BMPs shall also be identified by type, using the formal name of the GIP or BMP as established in Chapter 6 of this manual.
5. **Recorded documents required (record drawing).** All easements and survey plats pertaining to the land development shall be recorded with Jefferson County prior to submittal of the storm water record drawing. Copies of the recorded documents shall be included with the record drawing, as is indicated in the record drawing checklist.
6. **Nonconformance (record drawing).** In the event that the storm water record drawing indicates non-conformance with the approved SWMP or should the plan indicate, in the judgment of the department, that the constructed on-site storm water system does not meet the required storm water performance standards, the department will require submittal of additional information, including a description of the discrepancies between the constructed condition of the on-site storm water system and the approved SWMP, along with engineering calculations that demonstrate whether the constructed condition of the system complies with the required storm water performance standards.

Note: If the constructed condition of the on-site storm water system does not comply with the required storm water performance standards, the City of Birmingham Post Construction Storm Water Ordinance authorizes the department to require and approve a revised SWMP in advance of corrective actions, and a revised storm water record drawing in advance of permit closure.

2.5.4 Storm Water Practice Maintenance Agreement

The City requires execution of a maintenance agreement that addresses the long-term inspection and maintenance of the GIPs and/or BMPs for storm water quality and quantity control located on the property. A map depicting the location and type of all GIPs and BMPs located on the property must be included with the agreement. The agreement is executed by the property owner (typically this is the developer) and is provided with the SWMP submitted to the City for approval. Should the design, location, configuration, and/or type of any of the GIPs or BMPs on the property change after the SWMP is approved, the maintenance agreement and its map must be revised accordingly, executed, and provided with the storm water record drawing.

A blank maintenance agreement can be obtained from the Department of Planning, Engineering & Permits website.

2.6 City Storm Water Organization

Relevant to land development, administration of storm water management activities is carried out by Birmingham's Department of Planning, Engineering & Permits, which conducts planning and zoning activities and administers the City's storm water, building, and related codes to ensure public safety. Pertinent divisions within this department include Storm Water Management, Floodplain Management and Disaster Mitigation Services, Engineering Services, Building Permits, and Building Codes. The Birmingham Planning Commission, which includes the Zoning Advisory Committee and Subdivision Committee as wells as the Zoning Board of Adjustments are also aligned with the Department of Planning, Engineering & Permits. The storm water management responsibilities of these entities as they relate to land development are presented in **Table 2-1** and briefly discussed in the following subsections.

Table 2-1. Administrative Responsibilities for Storm Water

Agency	Relevant Responsibility
Local Agencies	
Storm Water Management	Lead agency for administration of the storm water management, storm water protection, and storm water fee ordinances; Plan review for pre-concept, soil erosion and sediment control; storm water management, and record drawing; Approval of Post Construction Storm Water Permit; Determination and approval of soil erosion and sediment control bond amount; Zoning-related storm water quantity and LID provision reviews
Floodplain Management and Disaster Mitigation Services	Floodplain information, including Floodplain Zone Overlay; Flood Hazard Development permit approval; Elevation and flood proofing certificates; No-rise certifications; Flood insurance program; Comments on soil erosion and sediment control when in floodplain
Engineering Services	Civil Construction permit review and approval (road, curb & gutter, etc.); driveway or sidewalk construction permits (both Engineering and Traffic Department approvals required)
Building Permits	"One stop permitting" application and approvals coordination, including final issuance of soil erosion and sediment control, storm water construction, civil construction, and other permits
Building Codes	Implementation and construction-stage enforcement of building codes, engineering design guidelines, and other ordinances
Planning Commission	Oversight of the Zoning Advisory Committee, Subdivision Committee, and planning-related codes, ordinances, and regulations; Adopts and amends the Comprehensive Plan with related Framework Plans
Zoning Board of Adjustments	Determinations on zoning ordinance variances and special exception requests

Agency	Relevant Responsibility
State Agencies	
Alabama Department of Environmental Management	NPDES permits: MS4 permits; Construction General permits; Industrial permits; State regulatory authority for water quality criteria/standards and implementation of Clean Water Act
Federal Agencies	
United States Environmental Protection Agency	NPDES permits: MS4 permits; Construction General permits; Industrial permits; Federal regulatory authority for water quality criteria/standards and implementation of Clean Water Act
Federal Emergency Management Agency	Floodplain/floodway mapping; Flood insurance information; Alteration of floodplains/floodways
United States Army Corps of Engineers	Section 404 permits (alteration to navigable waterways and wetlands)

2.6.1 Storm Water Management

From the land development storm water perspective, Storm Water Management is the agency that administers the Soil Erosion and Sediment Control and Post Construction Storm Water programs for Birmingham. Desktop responsibilities include participation in the pre-concept process (see Section 2.3) and review of Soil Erosion and Sediment Control and Post Construction Storm Water Permit applications and their associated storm water management, as-built, and Soil Erosion and Sediment Control plans. This agency sets the soil erosion and sediment bond amounts and performs reviews for limited zoning-related LID provisions.

Storm Water Management is also active on land development projects, performing inspections for soil erosion and sediment control and on-site storm water systems both during and after construction.

City of Birmingham
Stormwater Management

Storm Water Management facilitates and implements the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit issued to Birmingham by the Alabama Department of Environmental Management (ADEM). To carry out these responsibilities, the *City of Birmingham Post Construction Storm Water Ordinance* provides Storm Water Management personnel, through designation by the Director with the authority to, among other things: administer City regulations; provide storm water design and maintenance guidance; inspect private storm water management systems (both during and after construction); order corrective actions as necessary to properly maintain the systems so that drainage, flooding, and pollution impacts do not occur; and prepare and utilize storm water master plans for storm water management.

2.6.2 Floodplain Management Services

Relevant to land development storm water, Floodplain Management and Disaster Mitigation Services serves as the Federal Emergency Management Agency (FEMA) floodplain program administrator and contact for the Community Rating System (CRS) and National Flood Insurance Program (NFIP) for Birmingham. In this role, this office administers the City's flood protection provisions pertaining to land development, which are the Floodplain Zone Overlay contained in the *Birmingham Zoning Ordinance*. Through authority provided by the Ordinance, Floodplain Management and Disaster Mitigation Services establishes and amends regulations and guidelines for land developments in floodplains, while requiring all pavement installed in a floodway to be pervious; reviews, issues, and maintains local floodplain elevation and flood proofing certificates; provides floodplain map determinations and flood zone information; and reviews/approves

Flood Hazard Development Permits. Additionally, Floodplain Management and Disaster Mitigation Services will review storm water quantity and LID provisions, as it relates to the floodplain section of the zoning ordinance, and comments on Soil Erosion and Sediment Control plans for projects in the floodplain.

2.6.3 Engineering Services

Engineering Services reviews and approves the civil engineering-related aspects of private development plans, including roadway designs, roadway drainage, driveway and sidewalk permits, site storm water quantity control, subdivision-related review, and sanitary sewer. These permits are issued through the "One Stop Permitting" initiative with final permit issuance completed by Building Permit Services.

2.6.4 Building Permit Services

Building Permit Services oversee the "One Stop Permitting" initiative where applications are accepted, various reviews are coordinated, and final approvals are issued from one location in City Hall. When applications are received at the permitting counter, Building Permit Services is responsible for ensuring the requested information, plans, and fees have been submitted; distribution of the application to the appropriate review personnel; coordination with the applicant as needed; and issuance of the final permit approvals. In the context of land development storm water, Building Permit Services is responsible for the final issuance of the Soil Erosion and Sediment Control and Post Construction Storm Water Permits.

2.6.5 Building Codes

Building Code Services is responsible for the implementation and construction-stage enforcement of building codes and ordinances that have been adopted by the City of Birmingham such as engineering design guidelines, subdivision regulations, and zoning ordinances, which each have storm water-related guidelines and provisions.

2.6.6 Planning Commission

The Birmingham Planning Commission is the official planning agency for the City of Birmingham. Its broad responsibility is to plan for the physical development and/or redevelopment of the City and is also responsible for preparing maintaining the *City of Birmingham Comprehensive Plan* and related Framework Plans. The Planning Commission acts on a variety of planning-related issues such as:

- Reviews and approves construction projects by federal, state, or local governments and agencies;
- Considers appeals of Subdivision Committee decisions;
- Recommends initial zoning for annexed properties;
- Approves and adopts neighborhood improvement plans;
- Approves master plans for public institutions;
- Adopts and amends various elements of the Comprehensive Plan; and
- Reviews and recommends the adoption of various renewal, redevelopment, revitalization, and/or rezoning plans.

To assist in its planning responsibilities, the Planning Commission has delegated certain functions to several subcommittees. Among these are the Zoning Advisory Committee, which makes recommendations to the City Council on the merits of applications for changes in the zoning of property, and the Subdivision Committee who controls the subdivision of land and makes recommendations to the City Council regarding the vacation and dedication of public right-of-way.

2.6.7 Zoning Board of Adjustments

The Zoning Board of Adjustments is a quasi-judicial board comprised of seven members appointed by the City Council. The Zoning Board of Adjustments has three responsibilities:

1. To consider requests for a variance from the terms of the zoning ordinance when it is not contrary to the public interest. A variance is a relaxation of the terms of the zoning ordinance where, under

certain circumstances, a literal enforcement of the ordinance would result in unnecessary and undue hardship.

2. To determine whether to approve or deny application for a special exception to normal zoning rules when such a use or development is specifically not authorized or limited in the zoning ordinance. A special exception is a use not permitted by right but may be allowed if certain conditions are met.

3. To hear and decide appeals of the zoning ordinance when it has been alleged that there is an error in any order, requirement, decision, or determination made by a city official in the administration of the zoning ordinance.

2.7 Other Local Codes, Permits, and Plans

2.7.1 Overview

There are a number of local regulations, permits, and plans that are relevant to storm water designs for land developments. Each is listed below and summarized later in this section. While most are not explicitly directed at storm water design, they can influence the use of LID techniques for storm water and the design or construction of on-site storm water systems. These documents can be obtained from the City's website, **www.birminghamal.gov**, or obtained from the department.

- *City of Birmingham Post Construction Storm Water Ordinance*
- *City of Birmingham Post Construction Storm Water Design Manual*
- *The Storm Water Maintenance Manual for Property Owners*
- *Soil Erosion and Sediment Control Ordinance*, No. 99-131
- *Engineering Design Guidelines for Subdivisions or Commercial Developments*
- Floodplain Zone Overlay
- *Birmingham Zoning Ordinance*
- *Birmingham Subdivision Regulations*
- *City of Birmingham Comprehensive Plan*
- Watershed Management Plans
- *Storm Water Protection Ordinance*, No. 14-198
- *Storm Water Fee Ordinance*, No. 15-95

2.7.2 Storm Water Management Ordinance

This manual and the policies established herein are explicitly authorized by the *City of Birmingham Post Construction Storm Water Ordinance*. The ordinance directly regulates ***post-construction*** storm water management on development. The term "post-construction" literally means "after construction." When used in the context of storm water management, post-construction storm water refers to the management of storm water on a single land development (i.e., a subdivision or individual lot) ***after*** construction of the development is complete. Therefore, on-site storm water systems that are permanent features on a land development and manage storm water generated from the property are regulated by the ordinance. Post-construction storm water management is often confused with construction site storm water management, the latter referring to temporary erosion prevention, sediment control, and pollution prevention practices employed on a land development during its construction.

The *City of Birmingham Post Construction Storm Water Ordinance* regulates the design, construction, and maintenance of on-site storm water systems for new developments and redevelopments that result in land disturbance area of one acre or more. The ordinance addresses both post-construction storm water quantity (peak discharge and volume) and quality (e.g., pollutants). A local regulation to address post-construction storm water quality (i.e., pollutants) is required by Birmingham's NPDES-MS4 permit (see Section 2.8.1.2). In contrast, the regulation of post-construction storm water quantity is not typically required by state or federal government. However, it is a standard practice of local governments to protect the health, safety, and welfare of residents and businesses by reducing the potential for impacts caused by poor drainage practices and flood management.

The provisions of the *City of Birmingham Post Construction Storm Water Ordinance* are administered through two supporting documents: 1) the *City of Birmingham Post Construction Storm Water Design Manual* (see Section 2.7.3); and, 2) the *City of Birmingham Storm Water Maintenance Manual for Property Owners* (see Section 2.7.4). The former constitutes Birmingham's policy and guidance document for on-site storm water system design and construction while the latter serves as the policy and guidance document for system inspection and maintenance after construction is complete. Together, the ordinance and associated manuals provide a comprehensive set of regulatory tools and guidance for the life-cycle (design, operation, and maintenance) of storm water systems. The requirements established by policy statements in both manuals are made enforceable through the ordinance.

2.7.3 Storm Water Design Manual

The *City of Birmingham Post Construction Storm Water Design Manual* establishes the storm water design performance standards and storm water permit process and requirements for land developments that are subject to the *City of Birmingham Post Construction Storm Water Ordinance.* Additional policies contained in this manual include design specifications for GIPs, BMPs, and drainage systems; required design calculations and analyses; and requirements for the Post Construction Storm Water Permit and its associated plans and certifications. The manual also includes guidance on LID techniques, GIP/BMP selection, vegetation selection, installation and management, soil restoration and management, and the protection and management of GIPs/BMPs during construction. The intent of this manual is to provide a "one-stop shop" for site designers, in that it addresses post-construction storm water from the time a developer first considers a new land development or redevelopment to the time that construction is finished and the Post Construction Storm Water Permit is closed.

2.7.4 Storm Water Maintenance Manual for Property Owners

The *City of Birmingham Post Construction Storm Water Ordinance* requires that the property owner inspect and maintain the GIPs and BMPs located on their property. The *City of Birmingham Storm Water Maintenance Manual for Property Owners* is specifically intended for use by those who perform these duties. From a legal perspective, the responsibility for inspection and maintenance remain with the property owner. From a practical standpoint, however, these activities are often carried out by others, such as family members, tenants, property management businesses, and yard/landscape maintenance businesses. Regardless, the manual is written for the layman (i.e., someone who is not educated on storm water system design, construction, and maintenance) and provides performance standards, policies, guidance, and support tools in a relatively non-technical manner as compared to the *City of Birmingham Post Construction Storm Water Design Manual.* It also provides general educational information on storm water management, the importance of soil and vegetation, and how proactive protection, inspection, and maintenance of GIPs and BMPs can reduce the potential for costly repairs. The maintenance manual is based on information provided in the *Alabama LID Handbook* and the *Georgia Storm Water Management Manual.*

2.7.5 Soil Erosion and Sediment Control Ordinance

The *City of Birmingham Soil Erosion and Sediment Control Ordinance* (Ordinance No. 99-131) regulates storm water generated on land developments during land disturbing activities (e.g., clearing, dredging, grading, compacting, excavating, transporting, and filling of land). Since such activities are primarily construction related, soil erosion and sediment control regulations are often referred to by storm water practitioners and regulators as "construction storm water" requirements. The ordinance regulates these activities to prevent the discharge of sediment and other construction-related wastes into the public storm water system, onto adjacent or downstream properties, and into streams. Land disturbing activities such as agriculture, silviculture, home gardening, minor land-disturbing activities, minor maintenance, digging of wells, and railroad track repair or rebuilding are exempt from the ordinance. The ordinance is required by Birmingham's NPDES-MS4 permit (see Section 2.8.1.2).

2.7.5.1 Soil Erosion and Sediment Control Permit

A primary requirement of the *City of Birmingham Soil Erosion and Sediment Control Ordinance* is the requirement for a Soil Erosion and Sediment Control Permit prior to the commencement of land disturbing activities on projects of all sizes. Obtaining a permit requires the submittal and approval of a Soil Erosion and Sediment Control Plan and soil erosion and sediment control certification, and the posting of a bond for clearing, earthwork, and other land disturbing activity. A geotechnical certification is also required if the proposed land development is in an area susceptible to landslides. A drainage plan may also be required. Once the plan and associated items are approved, the permit is issued, and land disturbing activities can begin. Permit approval also initiates City inspections of the land disturbing activities for compliance with the approved plan and for evidence of off-site discharges of sediment and other construction related wastes. Because the success of the post-construction on-site storm water system is highly dependent on effective construction storm water management, the requirements of the ordinance are closely aligned with the guidance pertaining to construction site sequencing and management that is provided in the *City of Birmingham Post Construction Storm Water Design Manual.*

2.7.6 Engineering Design Guidelines for Subdivisions or Commercial Developments

The *Engineering Design Guidelines for Subdivisions or Commercial Developments* provides site designers with general information to assist in the preparation of civil construction plans that comply with the requirements of the City of Birmingham. The guidelines address the design of public works (streets, roads, and sidewalks). Historically, the guidelines also addressed public and private storm water drainage systems, including storm water detention/retention facilities; however, these requirements have been replaced with the *City of Birmingham Post Construction Storm Water Ordinance* and associated *City of Birmingham Post Construction Storm Water Design Manual.*

2.7.6.1 Civil Construction Permit

The *Engineering Design Guidelines for Subdivisions or Commercial Developments* require the issuance of a Civil Construction Permit to authorize the installation of public works. (Note: Issuance of a building permit **does not** authorize public works installations.) Application for a permit requires preparation and approval of civil engineering drawings that show the design of public works in compliance with Birmingham code as expressed in the guidelines, the *Birmingham Standard Specifications for the Construction of Public Works Projects,* and the *Birmingham Subdivision Regulations.*

2.7.7 Floodplain Zone Overlay

In 1995, Birmingham adopted the Floodplain Zone Overlay as part of the *Birmingham Zoning Ordinance* to protect flood-prone areas and regulate development in floodplains. This action initiated the City's participation in the NFIP, thus affording Birmingham residents and business with access to flood insurance and disaster assistance. Birmingham's voluntary participation in the FEMA CRS further benefits local residents and business by providing all those who obtain flood insurance for property in Birmingham with reduced flood insurance costs.

The Floodplain Zone Overlay designates Birmingham's regulated floodplain areas and regulates (or prohibits) development and other encroachments within these areas. As a zone overlay, the floodplain provisions apply within a designated floodplain zone over any other zoning district established by the *Birmingham Zoning Ordinance.*

2.7.7.1 Flood Hazard Development Permit

The Floodplain Zone Overlay includes the requirement to obtain a Flood Hazard Development Permit. Obtaining this permit may require preparation and submittal of significant additional information or analyses depending on the situation of the proposed development (e.g., in a floodway, in a floodplain only, etc.). The overlay and corresponding permit application provide more information on specific requirements.

2.7.8 Zoning Ordinance

The City's first zoning ordinance (Ordinance No. 1809-F) was adopted in 1990 and been revised numerous times to reflect city desires for land development regulation. The ordinance is Birmingham's primary land use planning tool as it provides the regulatory framework of standards for different types of land uses (zones) and the relative locations of different zones to one another. These standards implement the goals of the *City of Birmingham Comprehensive Plan*.

Standards in the zoning ordinance include, but are not limited to, development density requirements by type of development (e.g., conservation subdivision, commercial, etc.) and standards for lot sizes and setbacks. These types of standards are related to the use of LID techniques and selection/design of GIPs and BMPs as they influence the amount, types, location, and placement of pervious (green) and impervious land cover on land development. Conservation subdivisions are particularly well-suited for LID applications in that they explicitly strive to preserve green spaces within developments by clustering homes, reducing lot sizes, and planning for undisturbed natural areas to enable the preservation and maintenance of environmental features, sometimes connecting such spaces along green space corridors.

The zoning ordinance also includes requirements for site plan development and approval. Site plans are required for most non-residential developments requiring building permits. Site plan contents and requirements are outlined in the zoning ordinance and include the detailed storm water and drainage designs provided in the SWMP.

2.7.8.1 Birmingham Character-Based Code

The City has adopted a supplementary set of development guidance criteria called the *Birmingham Character-Based Code*. This type of code is intended to facilitate predictable, contextually-based planning and development of walkable, mixed-use, human-scaled places of character. Relevant to storm water management for individual land developments, the *Birmingham Character-Based Code* includes standards on development density, recreational areas, and open space. Open space and recreational areas often serve multiple purposes and can be designed to meet all or portions of storm water design criteria.

2.7.9 Subdivision Regulations

The *Birmingham Subdivision Regulations* guide future growth and development within Birmingham by establishing design standards for streets, alleys, easements, paths, sanitary sewers, and public areas within subdivisions. The regulations also establish the review and approval process to subdivide a property from preliminary plat to final plat. The preliminary plat must include a conceptual storm water design showing general locations of LID features, GIPs, BMPs, and other structural practices that may be used to meet the storm water quality and quantity requirements set forth in the *City of Birmingham Post Construction Storm Water Ordinance* and *City of Birmingham Post Construction Storm Water Design Manual*. The final plat includes the approved post-construction storm water system identifying both structural and non-structural components.

Historically, the regulations also included minimal provisions for storm water drainage systems, such as storm water detention/retention facilities. These requirements are now addressed in the *City of Birmingham Post Construction Storm Water Ordinance* and associated *City of Birmingham Post Construction Storm Water Design Manual*.

2.7.10 Comprehensive Plan

The *City of Birmingham Comprehensive Plan* presents the overarching vison for the future of Birmingham as a community of choice and opportunity. Within the plan, this vision is translated into strategies and implementation tactics to spur community growth and expansion, economic development, renewal, and revitalization of urban areas, local and regional partnerships, and sustainability and green development. While the latter vision is most directly relevant to on-site storm water management, it is important to note that a site designer's decisions made for on-site storm water management on a single development can strongly affect the site's environmental and aesthetic impact that, in turn, can influence the environmental and aesthetic impact of surrounding and nearby properties, which can then influence community growth, economic development, urban revitalization, and other important aspects of the City's vision for the future.

The *City of Birmingham Comprehensive Plan* is a non-regulatory document. However, the vision, strategies, and tactics contained therein are implemented, to some degree, through the ordinances, codes, plans, and permits summarized in this section of the post-construction manual. The plan recognizes the importance of quality of life and economic prosperity supported by local water resources in Birmingham and therefore suggests policies to protect these resources. The plan sets goals through recommended policies such as:

- Encouragement of conservation and LID development techniques;
- Encouragement of natural drainage in storm water management systems;
- Encouragement for development that protects local water resources;
- Support for the reuse of brownfields; and
- Support for State Water Quality Standards (see Section 2.8.3) and enforcement.

The department measures its progress and performance in implementing these strategies via indexes and baselines related to blight, redevelopment, health equity, complete streets, and sustainability. In keeping with overarching goals of the *City of Birmingham Comprehensive Plan*, all the suggested policies stated previously are further realized in the *City of Birmingham Post Construction Storm Water Ordinance* and this manual.

2.7.10.1 Framework Plans

Framework Plans are non-regulatory planning documents created by Birmingham as extensions to the Comprehensive Plan. These smaller plans address planning issues and opportunities at a more focused, community-by-community level, ideally providing more refinement and responsiveness to the specific needs of the various smaller communities and areas within Birmingham. The goals and recommendations found in each framework plan are based around the following key topics: Community Renewal, Green Systems, Economic Vitality, Transportation and Infrastructure, Future Land Use, and Strategic Opportunity Areas. Each plan has unique goals for the community relative to these topics. Most notably for purposes of this manual, the Green Systems section of each framework plan generally acknowledges the value of and need to protect natural features within the community. This is a common goal between the framework plans and the guidance provided in the *City of Birmingham Post Construction Storm Water Ordinance* and this manual.

2.7.10.2 Watershed Management Plans

In keeping with recommendations in the *City of Birmingham Comprehensive Plan*, the department oversees development of comprehensive watershed management plans for key watersheds in the Birmingham area. The purpose of watershed management planning is to describe measures for achieve the water resources goals of a particular watershed, which generally include the improvement and protection of surface water quality and the reduction of flood impacts. These measures are discovered through extensive study of the existing, and sometimes expected future, hydrologic response to rainfall within a specific watershed, and the hydraulic response of the watershed's storm water drainage system, which includes both manmade (inlets, catch basins, pipes, ditches, culverts, and outfalls) and natural (streams) elements. Information provided by a watershed management plan can include, but is not limited to, storm water volumes, peak discharges, and timing for different types of storm events, and pollutants types, land-use based concentrations, and waterbody loadings during and after storm events. These study results can be analyzed to identify key drainage basins, land development or storm water design techniques, and specific drainage/pollutant management practices that, in turn, can be crafted into effective strategies to mitigate flood and/or pollutant impacts within the watershed. Plan recommendations are specific to the needs and conditions of each watershed and can vary widely depending on these factors. Broad examples of the different types of watershed management recommendations include addressing storm water issues through public Capital Improvement Projects (CIPs), developing partnerships with stream site property owners to establish buffer zones, and increasing or relaxing local storm water system design requirements in certain areas of a watershed to modify the hydrologic or hydraulic response to storm events.

At the writing of this manual, Birmingham has a Watershed Management Plan for Village Creek and is developing one for Valley Creek. These plans are locally-derived, non-regulatory documents that recommend flood and/or pollutant mitigation strategies. They do not establish specific policies or specifications for land development and storm water management design. However, the wealth of detailed information provided by such plans can be, and often are, used for regulatory purposes. In fact, the *City of Birmingham Post Construction Storm Water Ordinance* authorizes the use of watershed management plans to increase, relax, and even waive certain storm water design requirements or to provide additional incentives for the use of certain storm water management or land development approaches, such as LID techniques or green corridor connectivity, which are determined to be desirable within key drainage basins for improved storm water management.

2.7.11 Storm Water Protection Ordinance

The *Birmingham Storm Water Protection Ordinance* (Ordinance No. 14-198) is required by Birmingham's NPDES-MS4 permit (see Section 2.8.1.2). The ordinance prohibits the discharge or dumping of pollutants into the storm water drainage system and streams. Pollutants from construction and land disturbing activities are included, and the ordinance refers directly to the *Soil Erosion and Sediment Control Ordinance*. While the bulk of this ordinance does not impact or influence land development or the design and construction of on-site storm water systems in Birmingham, it does include a notable provision for plan submittal. Specifically, the ordinance requires that any person who has a NPDES permit for land disturbing activities, such as an Alabama Construction General Permit issued by ADEM, must provide a copy of the permit, its notice of intent (NOI), related storm water pollution prevent plan, and monitoring results to the City. This requirement is included as a required item in the SWMP checklist provided in Appendix B of this manual.

2.7.12 Storm Water Fee Ordinance

The *Birmingham Storm Water Fee Ordinance* (Ordinance No. 15-95) authorizes the City to levee a recurrent fee on each parcel of property in the City (unless exempted) for purposes of funding the City's storm water management program. The City's program includes a myriad of services, including storm water regulation and permitting for land developments both during and after construction; participation in the NFIP and CRS program; compliance with state and federal water resources and storm water regulations and permits; public land development planning, design, construction, and project management; Capital Improvement Program (CIP) planning, design, construction and project management; flood and pollution complaint response; and the inspection, maintenance, and repair of the public storm water drainage system.

The ordinance does not have any provisions that directs planning and design for on-site storm water system management or land developments in general. However, site designers should note that the amount of the storm water fee for an individual property is directly proportional to amount of impervious surface area on that property. In short, the more impervious area, the higher the fee. The annual fee for commercial properties is capped at $3,000. For many developments, the use of LID techniques that conserve green space or reduce the amount of impervious area on a property can serve to reduce the storm water fee for the property.

2.8 Federal and State Regulations

Federal and state regulations that have an impact on on-site storm water design for land developments in Birmingham, either directly or indirectly, are summarized below. Persons that undertake land development activities are responsible for obtaining all applicable state and federal permits prior to initiating various local permit applications unless otherwise specified.

2.8.1 The NPDES Permit Program (Federal)

The NPDES permit program was created in 1972 under the Federal Clean Water Act (CWA) to address pollution in waters of the U.S. through the regulation of the sources that discharge pollutants to those waters. The regulation of storm water discharges is a significant component of the program. The federal NPDES program is administered by the United States Environmental Protection Agency (EPA) who delegates this authority to most U.S. states. In Alabama, administration and enforcement of the NPDES permit program has been delegated to ADEM.

The NPDES storm water program regulates storm water discharge from three potential sources: municipal separate storm sewer systems; construction activities; and industrial activities. Operators of these sources might be required to obtain an NPDES permit before they can discharge storm water. This permitting mechanism is designed to prevent storm water from washing harmful pollutants into local surface waters (www.epa.gov/npdes).

Relevant to land development, ADEM established Alabama NPDES permits for municipal storm water discharges from a MS4 and for construction storm water discharges (General NPDES Permit ALR100000). These permits are discussed in the following sections.

2.8.1.1 Alabama Construction General Permit

ADEM regulates construction storm water discharges and requires coverage under the Construction General Permit (permit number ALR100000) for all construction sites disturbing one acre or more or disturbing less than one acre if they are part of a larger common plan of development. The Construction General Permit has criteria related to stream buffers, stabilization timelines, construction best management practices plans, erosion and sediment control design, and more. This permit is renewed every five years, consistent with the EPA Construction General Permit cycle and requirements.

Information on the Alabama Construction General Permit is available on the ADEM website, www.adem.state.al.us.

2.8.1.2 Alabama NPDES Municipal Storm Water Permit

A MS4 is a conveyance or system of conveyances owned by a state, city, town, or other public entity that discharges storm water to waters of the U.S. EPA developed NPDES-MS4 permits to address the polluted storm water that is transported through MS4s and then often discharged, untreated into local water bodies. MS4 operators (typically a local government of a certain population or density) are required by EPA or their state regulatory authority to obtain an NPDES-MS4 permit to authorize discharges of storm water from MS4 outfalls. The permit requires MS4s to perform activities that will reduce or eliminate storm water pollutants to the maximum extent practicable. In turn, the local government implements a set of storm water management measures to meet these requirements, including education and outreach activities, storm water system mapping and operation, structural and non-structural storm water controls, and ordinances and supporting programs to address illicit discharges, erosion and sediment control, and post-construction storm water for land developments.

In general, MS4 permits are renewed every five years consistent with the EPA General MS4 permit cycle, often with some degree of change to permit requirements as the renewals occur. However, in many cases, permit renewal can take much longer. The City of Birmingham received its first MS4 permit from ADEM in 2001 and its most subsequent (renewed) permit in 2018. Regardless, as a regulated MS4, Birmingham is subject to the conditions of its effective NPDES-MS4 permit until such time that a new one takes effect, whether this occurs within the normal 5-year time frame or longer. Today, most Alabama MS4 permits have similar requirements pertaining to discharges of polluted storm water from construction sites and from land developments after construction is finished. The general following requirements of the MS4 permit are pertinent to new development.

- New developments and redevelopments that disturb more than one acre of land must minimize to the maximum extent practicable the discharge of pollutants during and after construction activities.
- All BMPs, whether temporary or permanent, must be maintained throughout its life.
- The City must ensure through education, plans review, inspections, and enforcement that the above criteria are being met.
- The City must ensure through a long-term BMP operation and maintenance program that all permanent BMPs are maintained in perpetuity.

2.8.1.3 Alabama Industrial Storm Water Permit

ADEM's Industrial Program develops and regulates the NPDES program for industrial sources. Owners of industrial facilities that will discharge pollutants into the waters of the State of Alabama must first obtain coverage under a valid NPDES permit. Both Individual and General permits can be obtained. Alternately, ADEM also issues No Exposure Certifications for Exclusions from NPDES Storm Water Permitting for industrial facilities that take steps to prevent storm water pollution by eliminating exposure of potentially polluting activities or spaces to rainfall and storm water. More specific information on which industrial activities are subject to the NPDES Industrial Program requirements is available on the ADEM website, www.adem.state.al.us.

2.8.2 Clean Water Act Section 401 Water Quality Certification

Section 401(a)(1) of the CWA, 33 U.S.C. Section 1251, et seq., requires that certain dredge and fill activities obtain a state Water Quality Certification (WQC). In Alabama, ADEM administers certain aspects of this program with involvement from other state and federal agencies. The federal statutes that play a primary role in the WQC program relevant to private land development in Birmingham are listed below.

- Section 10 of the Rivers and Harbors Act of 1899, as amended, prohibits the unauthorized alteration, including excavation or filling, of any navigable water of the U.S.; and

- Section 404 of the CWA, as amended, which requires that the United States Army Corps of Engineers (USACE) regulate and permit dredge and fill activities in watersheds and navigable waters of the U.S., including wetlands.

Information on the CWA Section 401 WQC in Alabama is available on the ADEM website, www.adem.state.al.us.

2.8.3 ADEM Water Quality Programs

Beyond the NPDES program, ADEM administers several other programs related to surface water quality that can influence how the department implements storm water management standards for on-site storm water systems in Birmingham. The most relevant of these programs to Birmingham's post-construction storm water program are briefly described below. More information is available on the ADEM website, **www.adem.state.al.us**.

- **Water Quality Standards –** The Water Quality Standards establish the use designations, and therefore the criteria intended to protect those uses, for all waters of the State in Alabama. Designated uses are listed in ADEM regulations at 335-6-11, and criteria are found in 335-6-10. ADEM uses the Water Quality Standards in combination with the 305(b) Report and 303(d) List (discussed in the following two paragraphs) to regulate storm water dischargers, including the City of Birmingham, via NPDES permits and other requirements. **Birmingham's NPDES-MS4 Permit requires that pollutant discharges from the City's MS4 not cause, nor contribute to, violations of the Alabama Water Quality Standards**.

- **Water Quality Report to Congress (305(b) Report) –** The 305(b) Report is a biennial report that provides a summary of activities related to surface water quality and an assessment of surface water quality conditions in Alabama. The report is produced by ADEM and submitted to PA as required by the U.S. CWA.

- **List of Impaired Waters (303(d) List) –** Section 303(d) of the Federal CWA requires ADEM to list the segments of rivers, streams, lakes, reservoirs, and estuaries that do not fully support their current use(s), as designated by the Alabama Water Quality Standards and determined using the surface water condition assessment published in the 305(b) Report. Such waters are considered "impaired" and, therefore, included on the 303(d) list, produced biannually by ADEM.

- **Total Maximum Daily Load (TMDL) Development –** The State of Alabama is required by EPA to establish a TMDL for the waterbodies included on the 303(d) list, specifically for each waterbody's pollutant(s) of concern. TMDL development is a determination of the amount of each pollutant causing the water quality impairment that can be allowed to discharge to the waterbody such that the applicable Water Quality Standard(s) for the waterbody is maintained. **Birmingham's NPDES-MS4 Permit requires that pollutant discharges from the City's MS4 comply with TMDLs, where applicable**.

As stated previously, the *City of Birmingham Comprehensive Plan* and related framework plans recognize the importance of quality of life and economic prosperity supported by local water resources in Birmingham with a goal to support Water Quality Standards and enforcement. The minimum performance standard for storm water quality that is established in Chapter 3 of this manual directly supports this goal by maintaining the City's compliance with its NPDES-MS4 permit. When minimum standards are insufficient, **the *City of Birmingham Post Construction Storm Water Ordinance* provides the department with the authority to require compliance with different or more stringent standards where water quality conditions indicate a need.** For example, the redevelopment of a brownfield property (e.g., an old iron works) can revitalize underused or blighted areas in Birmingham, resulting in greater community prosperity and economic improvements. However, probable contamination of the property's soil with zinc and other metals could predicate the need for different storm water requirements than those established in Chapter 3. These different standards would be determined by the department, ensuring that local water resources are protected during and after property redevelopment but not resulting in requirements that are so overly burdensome that they discourage redevelopment of the property.

The *City of Birmingham Post Construction Storm Water Ordinance* requires that the department evaluate the need for alternate storm water standards using the 303(d) list, published TMDLs, and local Watershed Management Plans, combined with an understanding of the past land use, flood, and pollutant history of a property, and the property's proposed future land use. Specific policies and conditions related to the use of more stringent standards for land developments, such as the discharge to waters listed as impaired or that have published TMDLs, are provided in Chapter 3 of this manual.

2.8.4 United States Endangered Species Act

In 1973, the U.S. Congress passed the Endangered Species Act (the Act), which recognized that:

- Various species of fish, wildlife, and plants have been rendered extinct because of economic growth and development un-tempered by adequate concern and conservation;
- Other species of fish, wildlife, and plants have been so depleted in numbers that they are in danger of, or threatened with, extinction; and
- These species of fish, wildlife, and plants are of aesthetic, ecological, educational, historical, recreational, and scientific value to the U.S. and its people.

The intended purpose of the Act is to provide a means by which the ecosystems upon which endangered and threatened species depend may be conserved and to provide a program for the conservation of those species. In Alabama, the United States Fish & Wildlife Service (USFWS) administers the Act through the assistance of its Alabama Ecological Services Field Office.

When a species is proposed for listing as endangered or threatened under the Act, the USFWS must consider whether there are areas of habitat believed to be essential to the species' conservation. Those areas may be proposed for designation as "critical habitat." Such designation does not necessarily restrict further development in the area. Rather, it serves as a formal reminder to federal agencies that they must make special efforts to protect the important characteristics of these areas. Informally, other stakeholders, such as local governments can use these listings and habitat designations to direct their own efforts toward species protection. More information on the Act, critical habitat designations, and the specific threatened and endangered species in Jefferson County is provided on the USFWS website, www.fws.gov.

As stated previously, the *City of Birmingham Comprehensive Plan* and related framework plans recognize the importance of natural areas, wildlife habitat, and environmentally sensitive areas (such as designated critical habitat) to the quality of life and economic prosperity in Birmingham. The plans include goals that strive to preserve natural and environmentally sensitive areas and reinvest in existing communities as a means of conserving resources and sensitive environments. The *City of Birmingham Post Construction Storm Water Ordinance* and the associated policies defined in this manual support these goals by emphasizing and encouraging redevelopment over new (i.e., green) development and recognizing that critical habitats may require more stringent storm water requirements for land development. **The *City of Birmingham Post Construction Storm Water Ordinance* provides the department with the authority to require more stringent standards where threatened and endangered species listings and/or critical habitat designations exists should pollution reduction in post-construction storm water be a possible mitigation measure.** Policies and conditions related to the use of more stringent standards related to this authorization are provided in Chapter 3 of this manual.

References

Alabama Department of Environmental Management website, www.adem.state.al.us, October 2017.

City of Birmingham, Alabama. *2012 City of Birmingham Comprehensive Plan*, 2012.

United States Environmental Protection Agency website, www.epa.gov, September 2017.

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Chapter 3. Design Policies & Performance Standards

Comprehensive performance standards address the full spectrum of storm water impacts encountered in Birmingham: stream and lake pollution; channel erosion and property loss; and, minor and major flooding.

Design Policies and Performance Standards

Storm Water Quality Protection

Birmingham's storm water quality protection standard promotes hydrologic mimicry, yet provides a multitude of design options and an alternate compliance approach to ease the path to compliance. This approach provides substantial design flexibility while still meeting water quality goals.

Birmingham's storm water policies promote hydrologic mimicry by recognizing the storm water value of preserved mature trees and native soil, and by offering incentives and credits for the use of Low Impact Development techniques and Green Infrastructure Practices.

LID/GIP Design Credits and Incentives

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3.1 Introduction

This section presents the comprehensive set of policies and performance standards for storm water management planning and design for land developments in the City of Birmingham. The policies provided in this chapter directly support the requirements for applicable new developments and redevelopments established in the *City of Birmingham Post Construction Storm Water Ordinance*. These policies are enforceable as the reference standards authorized by the ordinance.

3.2 Terminology

Terms defined in the ordinance and used frequently in this chapter are restated here to support the reader.

- The "**Director**" is the Director of the Department of Planning, Engineering & Permits or his/her authorized representative.
- A "**new development**" is any track, lot, or parcel of land, or combination of contiguous tracts, lots, or parcels of land which are in one ownership, or which are owned by two or more parties, and for which improvements of the land from a natural, entirely unimproved, condition are proposed or planned as a unit, subdivision, or project. New development includes land that has been used previously for livestock or crops, or has been previously grubbed, stripped, graded, and/or revegetated from a natural, entirely unimproved condition, provided that impervious surfaces were not previously placed or demolished thereon.
- A "**performance standard**" is the benchmark against which the design of the storm water drainage system, or a specific component of the system, is measured. A design must meet the performance standard for it to be deemed compliant.
- The "**pre-construction condition**" is the existing condition of the property at the time the application for a Post Construction Storm Water Permit is submitted, prior to any clearing, grubbing, grading, construction, or demolition done in preparation for the proposed new development or redevelopment. For new land developments, the pre-construction condition will be an undeveloped condition. For redevelopments, the pre-construction condition will be a developed condition. If demolition of pavement or structures has already occurred in preparation for the proposed redevelopment when the application for a Post Construction Storm Water Permit is received, the pre-construction condition shall be the previously developed condition of the property, as obtained from aerial photography, historical mapping, or other reliable source of land cover information.
- A "**redevelopment**" is an expansion, renovation, rebuilding, demolition and construction, or other further improvement of any previously improved tract, lot, or parcel of land, or combination of contiguous tracts, lots, or parcels of land which are in one ownership, or which are owned by two or more parties, are proposed or planned as a unit, subdivision, or project. "Previously improved" includes, but is not limited to, the prior placement, construction, and/or demolition of buildings, roadways, sidewalks, parking areas, and other areas of concrete, asphalt, gravel, packed gravel, or other materials on the subject tract(s), lot(s) or parcel(s).

3.3 Introduction to Performance Standards

3.3.1 Performance Standard Summary

Birmingham's storm water performance standards are summarized in **Table 3-1**. Together, the standards provide the City with a comprehensive, integrated set of design requirements that address both storm water quality (pollutants carried in storm water) and quantity (drainage and flooding).

Table 3-1. Summary of Storm Water Design Performance Standards

Performance Standard	Summary Description
Storm Water Quality Protection	• Manage 100% of the treatment volume onsite to one of the following standards. • Rv Standard *(preferred)*: o *New developments*: Achieve a site-wide weighted Rv ≤ 0.22[1]; or o *Redevelopments*: Achieve an Rv ≤ 0.22 for the amount of added impervious area[1]. • TSS Removal *(fallback)*: Treat the remaining volume (that not managed by GIPs) to 80% TSS Removal.
Small Storm Extended Detention	• In some situations, provide extended detention of the 1-year, 24-hour storm event volume.
Overbank and Extreme Flood Protection	• $Qp_{post} \leq Qp_{pre}$ for the 2-, 10- and 25-year, 24-hour storm events; and • Safely pass the Qp_{100} from the property.
Downstream Flood Analysis	• $Qp_{post} \leq Qp_{pre}$ for the 2- and 25-year, 24-hour storm events at the site outfalls onto adjacent property and to a prescribed 10% point downstream.
Drainage System Design	• Design inlets, box culverts, and pipes for the 25-year, 24-hour storm event.

[1] Some sites may be eligible for Rv credits or other incentives (see Chapter 4).
[2] Qp = Peak discharge for a specific design frequency storm. Qp_{post} = The peak discharge for a specific design frequency storm in the post-construction (i.e., proposed) condition. Qp_{pre} = The peak discharge for a specific design frequency storm in the pre-construction (i.e., existing) condition.

As indicated in Table 3-1, storm water quality is addressed using a dual-pronged standard. Designs must meet one of the two performance standards: Rv ≤ 0.22 or 80% Total Suspended Solids (TSS) Removal. The Rv Standard is met using a prescribed storm water volume reduction method (the Rv Method) focused on reducing pollutant discharge primarily using the natural hydrologic mechanisms of infiltration, evapotranspiration, and soil filtration or using methods for runoff capture and reuse. These mechanisms are preferred for storm water control because they work through both non-structural Low Impact Development (LID) practices and constructed Green Infrastructure Practices (GIPs). These practices can reduce the volume of storm water that must be managed by the onsite and offsite storm water systems. More information on the Rv Standard and Method is provided in Section 3.7.2 of this chapter and in Chapter 4.

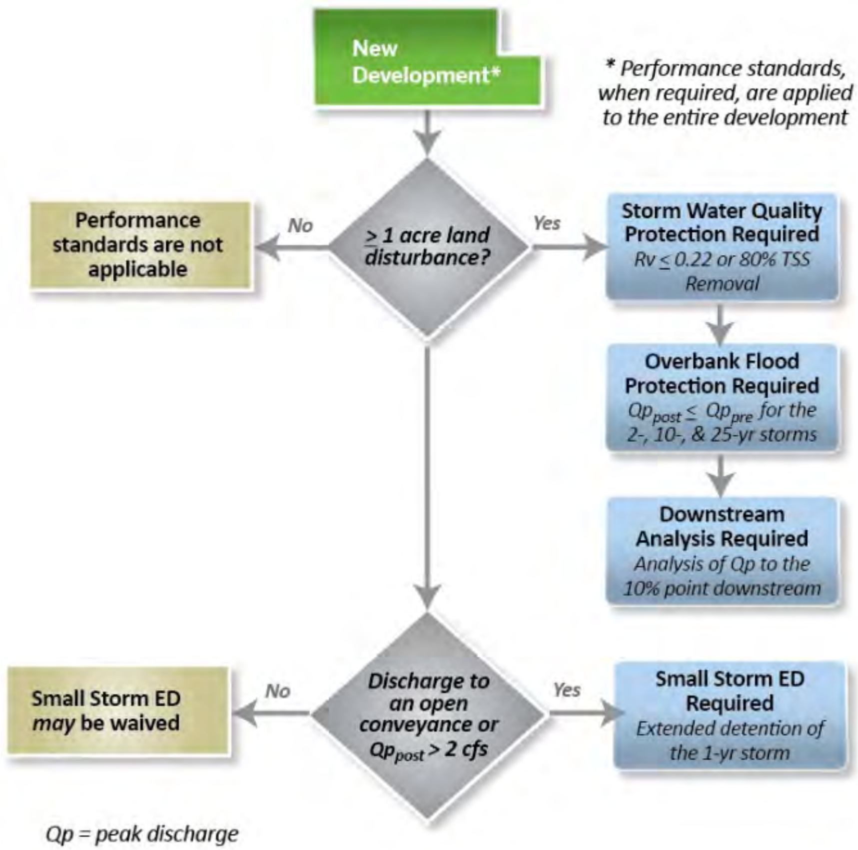
Alternately, designers can choose to implement the fallback standard of 80% TSS Removal. There is no penalty for use of the fallback standard. It targets the use of more traditional best management practices (BMPs) to filter, settle, or otherwise physically separate remove pollutants from storm water prior to discharge from the site. Designers who select the 80% TSS Removal Standard are still encouraged to implement the Rv Method as much as feasible before switching to an 80% TSS Removal calculation. Any storm water managed by a GIPs is subtracted from the required treatment volume, thus reducing the amount of storm water that must be managed to the 80% TSS Removal Standard.

Moving beyond the storm water quality protection standard, more traditional civil engineering standards are used for small storm extended detention, flood protection, downstream flood analysis, and drainage system design. The policies relevant to each of the performance standards summarized in Table 3-1 are provided in Sections 3.4, 3.5, and 3.6 of this chapter. Calculation methods, parameters, and guidance used to comply with these standards are provided in Chapter 4.

3.3.2 Application to New Developments

The *City of Birmingham Post Construction Storm Water Ordinance* is generally applicable to new developments that will disturb one acre or more. Beyond this threshold, all performance standards will be applicable to most new development projects. However, some standards can be waived (or increased) by the Director based on certain conditions established in the ordinance. General performance standard applicability for new developments is depicted in **Figure 3-1**.

Figure 3-1. Performance Std. Applicability for New Developments



3.3.3 Application to Redevelopments

General performance standard applicability for new developments is depicted in **Figure 3-2**.

The *City of Birmingham Post Construction Storm Water Ordinance* is generally applicable to redevelopments that will disturb one acre or more. However, the applicability of individual performance standards can vary, depending the circumstance of the redevelopment. As the figure shows, all performance standards may be waived if there will not be an increase in impervious area as a result of the proposed redevelopment.

It is important to note that the *City of Birmingham Post Construction Storm Water Ordinance* allows storm water performance standards for redevelopment to be applied only to the amount of added impervious surface that will result from the proposed redevelopment. This will be the case for most redevelopments, unless the Director requires a more stringent design as a result of criteria established in the ordinance (e.g., a history of flooding downstream). To facilitate the determination of the amount of impervious surface on a planned redevelopment, the definition of impervious surface is provided in **Table 3-2**.

When designing storm water controls for a redevelopment, the designer can choose the area(s) of impervious surfaces where the performance standards will be applied. Stated otherwise, the impervious area managed by new storm water practices does not necessarily have to be the new impervious area that will result from the proposed redevelopment. Ideally, the area to be controlled will be those that have the potential to cause the greatest negative storm water impacts, such as any existing directly connected impervious areas.

Figure 3-2. Performance Std. Applicability for Redevelopments

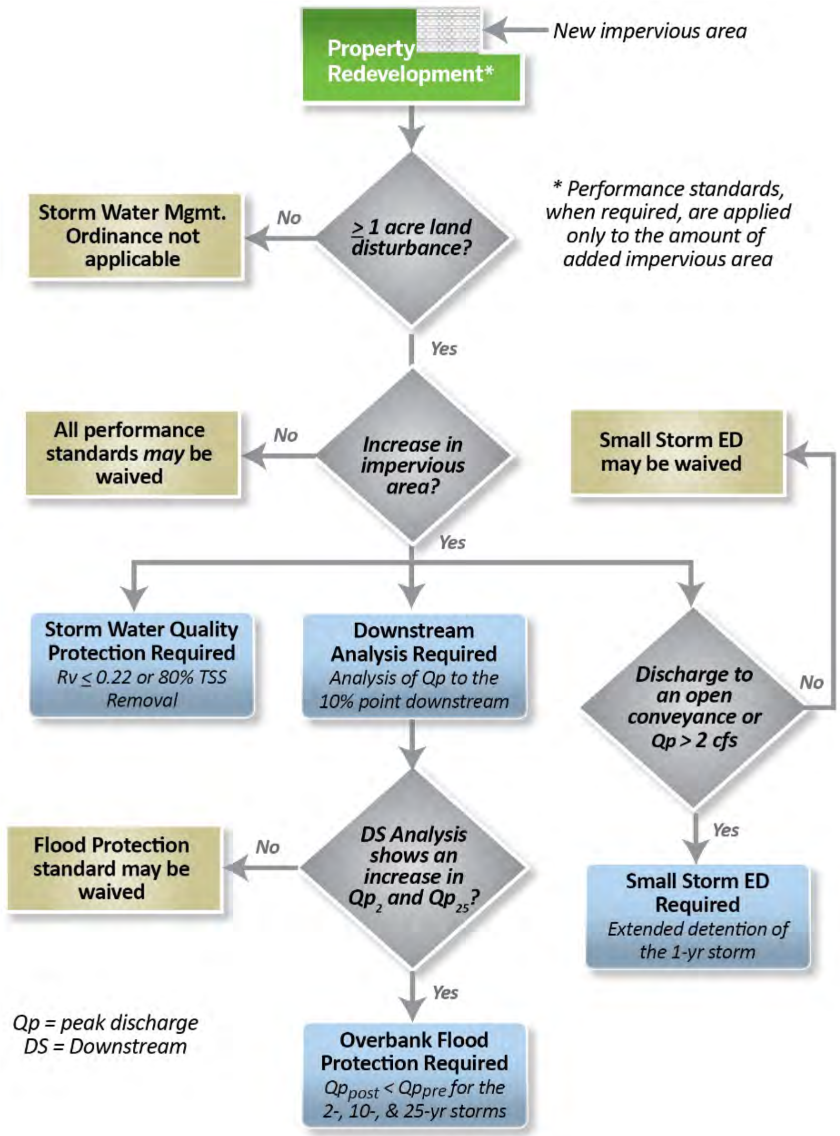


Table 3-2. Definition/Description of Land Surface Types

Performance Standard	Summary Description
Impervious Surface	Impervious cover is any land cover material that impedes or prevents the natural infiltration of water into the soil. Examples of impervious surfaces include roofs, streets, driveways, parking areas, patios, sidewalks, tennis courts, solid decks, and other concrete or asphalt paved areas. Areas covered by paver blocks, gravel, "crusher stone', or other material and used as vehicle driveways, travel ways, or parking are also considered impervious cover unless the cover will be specifically designed and constructed to allow infiltration of storm water.
Pervious Surface	Any land cover that does not fit the definition of impervious surface provided above. Examples of pervious surfaces include forests and wooded areas, meadow, grass, plant beds, areas of bare soil, areas of erosion, and Permeable pavement (e.g., asphalt, concrete) and paver block areas that are (or will be) designed to infiltrate storm water (with or without an underdrain) are also pervious areas.

3.4 Storm Water Quality Protection

3.4.1 Policies

The following general policies shall apply to developments and redevelopments that are required by the *City of Birmingham Post Construction Storm Water Ordinance* to meet the storm water quality protection standard (herein referred to as "applicable developments").

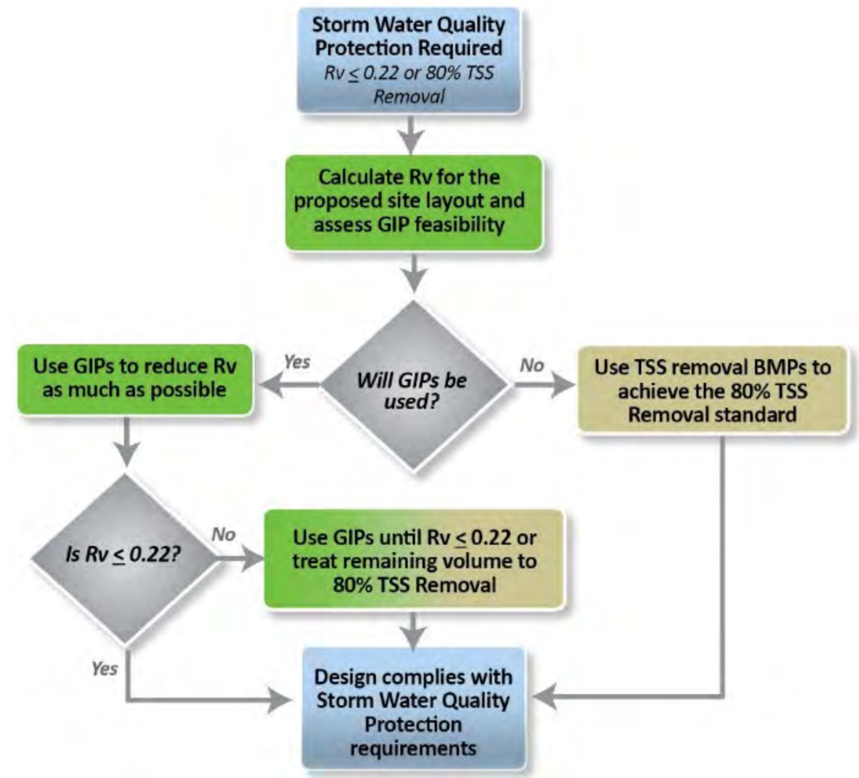
1. **Performance standards defined.** Storm water quality protection shall be provided to manage 100% of the treatment volume onsite using one of the following standards. The treatment volume is based on the 1.1-inch rainfall

   Rv Standard (preferred): Applicable developments shall be designed and constructed to achieve a volumetric runoff coefficient (Rv) less than or equal to 0.22 ($Rv \leq 0.22$) and shall manage the entire treatment volume for a 1.1-inch rainfall using on-site GIPs. It is possible to gain credits toward meeting the Rv Standard based on the type of development or use of specific GIPs such as reforestation. Developments that achieve the Rv Standard, including those that are adjusted using Rv Credits (see Section 3.4.4.2), are exempt from application of the TSS Removal Standard (see next paragraph). More information on the Rv Standard, credits, and design calculations (the Rv Method) are provided in Sections 3.4.4.2 and 3.7.2 of this chapter and in Chapter 4.

   TSS Standard (fallback): Applicable developments shall be designed and constructed to achieve 80% TSS Removal <u>for the remainder of the treatment volume</u> not captured using GIPs. When no GIPs are used, the entire treatment volume must be treated to 80% TSS Removal.

2. **Design procedure.** In applying one, or a combination of, the performance standards, the design procedure shown in **Figure 3-3** shall be followed.

Figure 3-3. Design Procedure for Storm Water Quality Protection



3. **Infiltration Feasibility Form required for certain GIPs.** As indicated by the second box in Figure 3-3, GIP should be considered examined for every applicable development as they can reduce the volume of storm water discharged from the site. An initial consideration of GIP feasibility is done during the pre-concept planning process (see Chapter 2). More involved assessment techniques may be necessary at the design stage, such as infiltration tests, soil borings, and capacity analyses (Appendix E). When GIPs that function using infiltration (with or without an underdrain) will be included in the site design, the Infiltration Feasibility Form (Appendix B) must be included with the Storm

Water Management Plan (SWMP). The form lists common site conditions that can limit the use, or influence the design, of infiltration GIPs. Completion and submittal of the form is a safeguard against improper selection or design of the GIP.

3.4.2 Choosing a Standard (Rv or 80% TSS Removal)

Designers are encouraged to use LID and GIPs whenever feasible to reduce volume of storm water runoff. However, while the Rv Standard is preferred because it results in reduced storm water volumes, certain conditions can limit or prohibit the use of GIPs on a land development. Typically, these concerns pertain to infiltration-based GIPs where infiltration of storm water could cause a negative impact or where there is insufficient hydrologic capacity. However, other conditions should also be considered, such as the ability of the future land owner to operate the practice (as in a cistern). Ultimately, sound judgement must be used when selecting the appropriate storm water management practices for a property.

One purpose of the pre-concept plan is to provide early identification of any opportunities or limitations for GIPs on a proposed development. Ideally, this will allow the site designer to determine the storm water quality protection performance standard most appropriate for his/her design. Site designers are encouraged to discuss potential GIP limitations with City staff during the pre-concept conference. As well, the design selection information and specifications contained in the Infiltration Feasibility Form and in the GIP selection information provided in Chapter 6 can help designers determine GIP feasibility.

3.4.3 Special Conditions

The *City of Birmingham Post Construction Storm Water Ordinance* includes a provision which allows the Director to impose alternate or more stringent storm water quality protection requirements under certain special conditions. Consult the Ordinance for those conditions. Special conditions can be determined and discussed at the pre-concept conference. It should be noted that storm water quality protection requirements are predicated by the City's NPDES-MS4 permit and therefore a waiver of such requirements is unlikely. Offsite mitigation and fee-in-lieu programs are provided to allow added flexibility to meet storm water quality protection requirements when on-site conformance is difficult. See Sections 3.4.5 and 3.4.6 for more information on offsite mitigation and fee-in-lieu programs.

3.4.4 LID/GIP Design Credits and Incentives

Regardless of design goal (storm water quality protection or quantity control), the use of storm water LID/GIPs to manage the small storm water volumes has the added benefit of also reducing the amount of storm water that must be managed during any storm. Therefore, site designs may reap a number of positive benefits from the implementation of LID/GIPs including, but not limited to, smaller systems for on-site storm water management and lower construction costs. Birmingham has developed a strong program of incentives and credits to further encourage the use of storm water LID/GIPs. **Table 3-3** presents lists and summarizes these incentives and credits. More detail is provided in the sections that follow.

Table 3-3 Birmingham LID/GI Design Incentives

Incentive or Credit	Summary Description
Curve Number Adjustment	The curve number is adjusted to account for the storm water volume captured by GIPs.
Rv Standard Credits	An Rv Standard credit is provided for certain types of developments that inherently include storm water LID practices.
Multi-Benefit GIP Incentives	Design calculation parameters are adjusted in recognition of GIPs that provide multiple storm water quality benefits.
Inherent Storm Water Utility Fee Reductions	Storm water utility fees are inherently less when LID practices that reduce impervious surface area are applied on a property.

3.4.4.1 Curve Number Adjustment

The storm water treatment volume captured and removed using GIPs can be considered when designing storage BMPs to meet the flood protection performance standards. This is done by making an adjustment to reduce the curve number (CN) for the development based on the volume captured by the GIP. Curve numbers shall be defined for the proposed condition using the method(s) described in Chapter 4 of this manual prior to adjustment. The CN adjustment procedure is also provided in Chapter 4.

3.4.4.2 Rv Standard Credits

Birmingham has chosen to encourage certain types of developments that, when designed in combination with storm water LID practices, can directly support the City's goals for sustainability while having less impact on storm water quality when compared to developments designed using standard approaches. These types of developments are being encouraged using a crediting system that helps a land development to achieve the storm water quality protection standard. The types of development being promoted are listed below. Rv Credit policies, eligibility criteria, and calculation requirements are provided in Chapter 4 of this manual.

- Encouraging **brownfield redevelopments with planned green spaces** can result in less added impervious space within Birmingham than an equivalent new development and can revitalize areas of the City that have degraded over time.

- Encouragement of dense developments (e.g., developments with **high vertical density or clustered buildings with planned green spaces**) can result in reduced storm water volume per dwelling unit as compared to properties with widespread imperviousness and can help City planners promote downtown redevelopment and "pocket" green developments.

3.4.4.3 Multi-Benefit GIP Incentives

For the most part, LID practices and GIPs rely on the preservation or restoration of pervious land cover and native (or non-native but well-draining) soils. This promotes infiltration and, in the case of pervious (i.e., green) land cover, evapotranspiration. These GIPs can receive storm water from other areas of the development, thus providing multiple storm water benefits.

Alternately, other types of GIPs more explicitly mimic pre-construction hydrology than others by attempting to manage rainfall where it falls and over a relatively wide area, as opposed to just collecting and managing storm water from other areas in a relatively small structural facility. Green roofs and permeable/porous pavements and pavers are rather unique from other GIPs in that they serve the function of a traditionally impervious surface (e.g., a roof, a parking lot, a right-of-way, etc.) but can mimic large pervious areas because they infiltrate water into their structure, discharging no, or very little, storm water for the storm water quality event (1.1 inches).

3.4.4.4 Inherent Reductions in Storm Water Utility Fees

In Birmingham, storm water utility rates are calculated using the total area and area of impervious surfaces on a property. The amount of impervious surface and the fee calculated are directly proportional to each other - the higher the amount of impervious surface then the higher the storm water utility fee. This relationship between impervious surface and utility fee results in a "built-in" incentive for the use of some LID practices which target the preservation of pervious land cover and native soils (i.e., green space). In addition, some GIPs can preserve green space or return impervious areas to vegetated land cover (i.e.., reforestation and stream buffers). Others can mimic green spaces for small storms while providing a functional space (i.e., green roofs and pervious pavements or pavers). These LID/GIP conditions are reflected in the hydrologic computations in storm water quality design because they provide low Rv values and reduce treatment volumes. In flood and drainage system design, they have low Runoff

Coefficients (C), CNs, and can increase times of concentration (t_c). Therefore, it follows that the hydrologic mimicry provided by storm water LID practices and GIPs can also result in lower storm water utility fees than would be calculated using traditional site and storm water designs.

3.4.5 Fee-in-Lieu Program

This space reserved. Program under development.

3.4.6 Offsite Mitigation Program

This space reserved. Program under development.

3.5 Flood Protection

3.5.1 Overview

The *City of Birmingham Post Construction Storm Water Ordinance* requires adherence to three flood protection performance standards prior to discharge from the property:

1. Small stream extended detention;
2. Overbank and extreme flood protection; and,
3. Downstream flood analysis.

These standards are implemented by designing GIP/BMPs that will temporarily store storm water and then release it at a controlled rate. The primary purpose of flood protection standards is to provide for the safety of the general public and to protect public and private properties. Note that the ordinance includes a provision that allows the Director to impose alternative or more stringent flood protection requirements where a local watershed management plan, engineering study, or flood protection initiative indicates a need.

3.5.2 Small Storm Extended Detention Policies

The **small storm extended detention (ED)** performance standard addresses the potential for frequent localized nuisance flooding caused during smaller storms and protects local streams from frequent erosive flows. The *City of Birmingham Post Construction Storm Water Ordinance* provides a waiver of the standard:

- where the post-construction condition peak discharge at the outlet(s) of the development is less than 2.0 cfs at each offsite discharge location; or,
- for proposed developments that will discharge directly into open conveyances such as larger streams, rivers, wetlands, or lakes provided the discharge will not have an impact on stream bank or channel integrity.

Policies for the small storm ED standard are as follows.

1. **Small Storm ED performance standard defined.** The storm water volume from a 1-year frequency, 24-hour storm over the site, herein called the small storm ED volume (EDv), shall be captured and discharged over no less than a 24-hour period (extended detention). The 24-hour release period shall be measured from the approximate centroid of the inflow hydrograph to the approximate centroid of the outflow hydrograph (see Chapter 4 for more information).
2. **Alternative approaches allowed.** The Director may approve the use of an alternative approach for channel erosion protection if engineering analysis provided by the applicant shows, in the engineering judgement of the Director, that the alternative approach will offer equivalent or better protection.
3. **Outlet erosion protection required.** Erosion prevention measures, such as energy dissipation and velocity control devices, shall be provided at the outlet of GIP/BMPs, which provide channel erosion protection.

3.5.3 Overbank and Extreme Flood Protection Policies

The **overbank flood protection** standard reduces the potential for stream-side flooding that can be caused by the hydraulic stacking of peak discharges in local streams. This results from variations in hydrologic timing during more frequent, low- to moderately-sized storm events. In contrast, the **extreme flood protection** standard has been established to reduce the potential for localized and regional catastrophic flooding caused by very large storm events. Policies associated with these standards are as follows.

1. **Overbank Flood Protection performance standard defined.** Overbank flood protection shall be provided such that the calculated post-development peak discharge resulting from the 2-, 10-, and 25-year return frequency, 24-hour duration storm events does not exceed the same 2-, 10-, and 25-year return frequency, 24-hour duration storm events on the same site prior to development. This is achieved through detention of storm water from the design storms.
2. **Extreme Flood Protection performance standard defined.** The emergency spillway shall be designed to accommodate the estimated runoff from a rainfall event with a 100-year return frequency, 24-hour duration storm event without catastrophic damage to the facility or downstream areas.

3.5.4 Downstream Flood Analysis Policy

The *City of Birmingham Post Construction Storm Water Ordinance* also requires that a downstream flood analysis be performed. The purpose of the analysis is twofold: (1) to ensure that detention actually limits peak flow increases downstream; and (2) to look at the potential to waive detention if it is not needed due to the timing of downstream peaks at flow junctions. In the event that the flood potential increases, the detention design will need to be modified to address the problem or another alternative developed.

1. **Analysis Criteria.** The downstream flood analysis shall be applied at tributary junctions throughout the 10% downstream analysis area and after all other performance standards have been met (i.e., the analysis shall include the influence of on-site BMPs designed for flood protection purposes). The downstream analysis is often used in conjunction with flood protection analysis
2. **Downstream hydrologic analysis standard.** The downstream hydrologic analysis shall analyze the peak discharge for the 2- and 25-year return frequency, 24-hour duration storm events at the outfall(s) of the development and at each downstream tributary junction to the point(s) in the storm water system where the area of the portion of the site draining into the system is less than or equal to 10% of the total drainage area above that point.

   Land developments for which the downstream hydrologic analysis does not indicate an increase in peak discharges or downstream stream erosion are not necessarily exempt from conformance with the storm water quality, small stream ED, and drainage design performance standards. If peak discharge increases are identified in the 10% downstream analysis area, downstream flood protection measures shall be provided or changed such that calculated peak discharges for the 2- and 25-year return frequency, 24-hour duration storm events is no greater after development of the site than that which would result from the same duration storms in the same downstream analysis area prior to development. The Director may require additional analysis.
3. **Alternatives for flood protection measures.** Downstream flood protection measures can be provided by downstream conveyance improvements or purchase of flow easements in lieu of additional or larger on-site storage BMPs, subject to prior approval by the Director and satisfaction of all the following requirements.
   a. Sufficient hydrologic and hydraulic analysis must be presented that show that the alternative approach will offer adequate

protection from downstream increased flooding for all potentially affected downstream property owners.

b. The applicant is responsible for submittal and approval of any floodplain-related analyses and requirements, such as No-Rise analyses, a Conditional Letter of Map Revision (CLOMR) prior to construction, and/or a Letter of Map Revision (LOMR) upon completion of construction.

c. The applicant is responsible for all state and federal permits that may be applicable to the site including ADEM construction storm water and other state required permits or conditions and US Army Corps of Engineers Section 404 permits.

4. **No increase in peak discharge.** Land developments that are found through downstream analysis to not cause an increase in peak discharges are not exempt from conformance with the minimum standards for water quality protection and small storm extended detention (EDv) presented earlier in this chapter.

3.6 Drainage System Design Policies

3.6.1 Overview

The policies in this section address the performance standards required for the design of storm water drainage system components, including pipes, ditches, and culverts and their associated appurtenances, such as curbs, gutter, catch basins, outlets, headwalls, etc. Policies associated with design methods and parameters are provided in Chapter 4.

3.6.2 Performance Standards

The following performance standards are applicable for drainage system design.

1. **Design of storm water drainage collection systems.** The minimum return period to be used in the design of storm water drainage collection systems shall be the 25-year return frequency. For designs that require a hydrograph to assess the effects of storage and timing, a 25-year return frequency, 24-hour duration storm event shall be used. This standard may be adjusted by the Director to accommodate downstream pipe sizes.

2. **Design of box culverts and pipes.** The minimum return period to be used in the design of box culverts and pipes shall be the 25-year return frequency, 24-hour duration storm event.

3. **Use of more stringent standards.** Storm event return frequencies greater than the minimums stated in this manual may be used for storm water drainage system design as determined by the engineer of record. However, care should be exercised when selecting a return period so that downstream storm sewer systems are not adversely affected.

4. **Drainage systems located in floodplains.** Consult Birmingham's Flood Zone Overlay in the *Zoning Ordinance* for information on developments within or near a floodplain. It is the engineer of record's responsibility to determine if a storm water drainage system will be within a flood hazard zone and to design it in accordance with Birmingham and Federal Emergency Management Agency (FEMA) requirements.

3.7 Policy Background

The remainder of this chapter discusses Birmingham's storm water management goals which led to the development of the policies established previously in this chapter.

3.7.1 Storm Water Policy Goals

Birmingham's storm water requirements are predicated on the need to manage the flow of, and pollutants within, storm water that is generated on developed properties. A change in the hydrologic condition of a property occurs when natural land cover (trees, shrubs, and grasses) are replaced, even partially, by impervious surfaces (rooftops and pavement). This results in increases in storm water volume, flow rate, and pollutants and also can cause negative impacts such as flooding and stream degradation. Regulations at the federal, state, and local levels strive to eliminate, or at least lessen, these impacts through the use of storm water-minded site planning techniques and on-site structural storm water controls. More information on storm water impacts and the regulations that govern storm water management is provided in Chapter 1 of this manual.

The requirements provided in this chapter have been developed with consideration of:

- Past City storm water design policies that have proven effective;
- Storm water management approaches that are used successfully in other leading southeastern cities;
- Federal and state requirements for storm water management[1]; and
- Conditions or initiatives in Birmingham that can influence the storm water control design and suitability at the site level (e.g., soil types and conditions, downtown redevelopment, other City codes and plans).

The overall aim of the planning and design requirements herein is to provide an integrated approach to reasonably manage storm water quality and quantity on a developed property prior to its discharge onto adjacent properties, into the City's drainage system, or to a local stream. This can be achieved through implementation of the following storm water design principles upon which the performance standards are based.

1. **Protecting local water resources by requiring storm water quality control through the use of structural controls designed to limit the volume of storm water generated on a developed property and/or remove pollutants from storm water before it is discharged from the site.** Storm water volume limitations are provided by GIPs that depend on infiltration, evapotranspiration, or capture and reuse techniques to reduce storm water volumes. Alternately, pollutant removal is provided by BMPs designed to remove TSS and accompanying pollutants from storm water. TSS is considered by storm water practitioners to be an indicator, or measure, of typical storm water pollution.

2. **Promoting the use of LID techniques and GIPs to limit generation of storm water volume as a first consideration of site designers.** LID and GIPs primarily depend on the hydrologic cycle to manage storm water through: rainfall interception storage (leaf or landscape capture); infiltration (soil capture); and evapotranspiration (evaporation from the ground and through plant leaves).

3. **Managing the downstream flood potential through the use of runoff storage BMPs such as extended detention, detention, and retention.** Note that some pollutant removal BMPs can also assist in flood control.

4. **Implementing on-site pollution prevention practices that prevent pollutants from coming into contact with storm water in the first place is highly effective for storm water quality control.** Pollution prevention practices include structural methods, such as using covers and wastewater sewer connections for dumpsters, and procedural methods, such as regular sweeping of parking lots to remove trash, sand, and sediment.

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[1] More information on the various federal and state programs that set requirements for municipal storm water management can be found in Chapter 2 of this manual. These programs include the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit program and the National Flood Insurance Program (NFIP) under FEMA.

The planning and design requirements for storm water quality and flood protection defined in this chapter are intended to set forth policies that are reasonable in scope, flexible in practice, and effective in the management of storm water. Similar requirements have been implemented in other cities and states and have proven to be attainable on the vast majority of development sites. Locally-specific waivers and alternative practices can handle those more difficult sites.

3.7.2 Background on the Rv Standard and Rv Method

The Rv Method was developed to allow local governments and site designers to "measure" how a post-construction site design results in runoff that mimics pre-construction hydrology to the maximum extent practicable using LID and GIPs. In general, LID and GIPs strive to infiltrate, evapotranspire, or store and reuse storm water as much as possible, thus more closely mimicking a natural hydrologic cycle than standard storm water quality management practices. Therefore, by requiring site designers to start their design by considering the feasibility of GIPs through the initial step of the Rv Method, Birmingham is complying with the permit requirement to encourage LID and GIPs.

Referring to Figure 3-3, the leftmost diamond-shape in the figure indicates a preferred compliance standard of Rv ≤ 0.22. The Rv Method uses this single compliance metric, called the volumetric runoff reduction coefficient (Rv), to "measure" the percentage of precipitation that will run off a specific land cover on an average annual basis (see equation below)[2].

$$Rv = \frac{Average\ Annual\ Rainfall\ Capture}{Average\ Annual\ Rainfall}$$

In general, Rv is derived from national studies and standards and continuous simulation rainfall-runoff modeling using data from the local area which in this case is Birmingham. The Rv values included in Chapter 4 were derived for Birmingham to estimate storm water from storms of moderate intensity and meeting the NPDES-MS4 permit's design basis rainfall of 1.1 inches over 24-hours preceded by a 72-hour dry period. It was determined that Rv of 0.22 generally indicates 100% capture of the design basis rainfall. Thus, in the Birmingham area, hydrologic mimicry for the permit's design basis rainfall is established by achieving a Rv ≤ 0.22 for the proposed development. So, a minimum level of compliance with permit conditions translates to a local requirement that requires site designs to achieve a site-weighted Rv ≤ 0.22 and management of the entire treatment volume on-site.

The Rv Method makes compliance calculations for the Rv Standard easy because it does not require complex modeling of rainfall, soil infiltration, evapotranspiration, and GIP design. The modeling performed to establish a local relevancy to Birmingham's NPDES-MS4 permit requirements is already reflected in the Rv values used for the specific land cover (e.g., impervious surfaces, turf areas, forested areas) and soil combinations on a site.

The Rv Method centers on achievement of the target site Rv value through land cover and structural practice decisions. Different types of land cover are assigned different Rv values based on model results. For example, if open space can infiltrate or evapotranspire the storm water volume, then it can be credited for removing 100% of the pollutants within the storm water volume it removes. This allows open space to be recognized as an effective control. Even impervious surfaces capture a small amount of water and, therefore, do not generate 100% runoff. Thus, site layout and land cover decisions become critical aspects of storm water management design and understanding and

[2] Site designers should not confuse the volumetric runoff coefficient, Rv, with the Rational Method's runoff coefficient (C) used to calculate peak flow (Qp). Rv is a measure of runoff volume capture and C, which is used to calculate peak flow, are completely different parameters with completely different uses.

when calculating every aspect of a site's land and soil condition in relation to volume removal is important. In this way, the Rv Method emphasizes and places real value on the use of LID practices.

Using LID practices, such as minimizing clearing and grading, limiting impervious surfaces, and optimizing green spaces to prefer areas that have well-draining or moderately well-draining soils, will naturally result in a lower Rv value and, therefore, lower treatment volumes even before GIPs or TSS Removal BMPs are designed. As well, flood control detention facilities and storm water drainage systems will be smaller and require less labor and materials to construct. More green space and less infrastructure can often equal construction cost savings while enhancing the aesthetic value of a developed property. LID is discussed in greater detail in Chapter 5.

LID for storm water management is most effective when site designers consider the general design goals and principles for runoff reduction design at an early stage in the development planning process, ideally when site land use and layout is being conceptualized. This need stems from the fact that a site's pervious and impervious layout greatly influences the ability to reduce runoff, whether naturally using the sites inherent hydrologic characteristics or using engineered practices designed to infiltrate, evapotranspire, or harvest and use. The pre-concept plan process, described in Chapter 2, facilitates this early examination of a potential land development.

Once LID techniques are considered and designed, the Rv Method accounts for the management of storm water by GIPs by applying Rv credit to the area discharging to the GIP, effectively reducing the volume of runoff. Rv credits for GIPs are determined using continuous simulation models, based on Birmingham rainfall conditions and, generally, the GIP design specifications included in Chapter 6.

However, it is recognized that the use of GIPs to infiltrate, evapotranspire, or capture and reuse storm water may not always be practical or advisable. This is true anywhere, not just in Birmingham. There are a number of conditions, both natural and man-made, which may preclude the use of GIPs on some developments, including the presence of sinkholes, high water table, and existing soil contamination. So, while Birmingham prefers the use of GIPs to manage storm water because these practices can, collectively, reduce storm water pollutants and volumes that must be managed by the public storm water system and ultimately our local streams and lakes, City policy DOES NOT mandate their use. **In fact, the site designer is charged with selecting the most appropriate structural storm water control practices for the development based on site conditions, practice feasibility, the proposed land use, and maintenance needs of the practice.**

When GIPs are infeasible, proposed developments must still protect storm water quality. Birmingham provides a "fallback" standard of 80% TSS Removal for such sites. TSS removal is a common storm water quality standard in the eastern and mid-western United States. Meeting the 80% TSS Removal Standard will require the design and construction of TSS Removal BMPs (e.g., extended detention ponds, sand filters, manufactured treatment devices, etc.).

3.7.3 Context for the Dual Storm Water Quality Protection Standards

The storm water quality-based performance standards and supporting policies provided previously explicitly support Birmingham's compliance with the requirements of the NPDES-MS4 Permit. The permit targets post-construction pollutant reduction by requiring that post-construction runoff mimic pre-construction hydrology and that landowners and developers "implement systems of appropriate structural and/or non-structural BMPs designed to reduce the discharge of pollutants." The permit also requires that Birmingham encourage the use of LID and GIPs where feasible.

As indicated previously in this chapter, Birmingham's approach for compliance with the NPDES-MS4 permit is two-pronged. First, compliance always starts with an initial calculation of the site's Rv using Step 1 of the Rv Method (see Chapter 4 for calculation guidance). Within the context of Birmingham's storm water quality requirements, the Rv Method provides: 1) initial recognition and valuation of all green spaces on a site for storm water management for all developments, regardless of the use of GIPs; 2) a starting point for determination of the site's treatment volume (based on a 1.1-inch rainfall); and 3) a compliance calculation for the Rv Standard, should it be selected by the site designer.

The 80% TSS Removal Standard is included as the alternate (or fallback) standard. Ideally, it will be used only when the Rv Standard cannot be achieved. The 80% TSS Removal Standard provides greater flexibility for site designers while still ensuring storm water protection for local water resource. By implementing this two-pronged approach, Birmingham can comply with the permit using local regulations that are flexible enough to recognize the inherent difficulties in designing developments that mimic natural systems but can consistently and fairly be applied to all applicable developments. Compliance calculations and detailed design procedures for both the Rv Standard and Rv Method and the 80% TSS Removal Standard are provided in detail in Chapter 4.

References

City of Birmingham, Alabama. *2012 City of Birmingham Comprehensive Plan*, 2012.

Metropolitan Nashville and Davidson County, TN. *Volume 5 Low Impact Development Stormwater Management Manual.* February 2016

Chapter 4. Design Calculations

Design Principles

Ideally, site designers should seek to improve the effectiveness of natural systems rather than to ignore or replace them.

Design Calculations

Design calculation policies and guidance are provided to ensure design consistency and effectiveness, whether the designer chooses to use innovative, multi-functional controls or more traditional storm water practices.

Full Spectrum Benefits of LID

The storm water volume reductions that can result from the use of LID techniques are reflected in the reduced volumes and peak discharges that are calculated for the full spectrum of performance standards, from storm water quality and channel erosion protection, to minor and major flooding.

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4.1 Design Principles

This chapter provides the calculation methods and associated equations to support the requirements of *City of Birmingham Post Construction Storm Water Ordinance* and its supporting policies established in this manual.

The site design process presented in this chapter stems from a number of general principles for storm water management design that have become commonplace with the growth of low-impact development (LID) and green infrastructure techniques. Initially defined in the *Georgia Stormwater Management Manual* (ARC, 2016), the principles align well with concepts defined in the *Alabama LID Handbook* (ADEM, no date) and Birmingham's objectives for storm water management. These principals, presented below, guide the requirements for on-site storm water management in Birmingham.

1. **On-site storm water drainage system designs must address drainage and water quantity control, water quality protection, and in-stream channel erosion, ideally in an integrated fashion.**
   This principle stems from the need to reduce the existing negative storm water impacts that Birmingham has experienced (see Chapter 1), mitigate the potential for future negative impacts, and comply with state and federal storm water requirements. The design process described in this chapter facilitates implementation of comprehensive storm water performance standards that can limit, and even eliminate, negative impacts. Moreover, the process fully supports a flexible and regulatorily compliant storm water design methodology by including steps that promote consideration of cost-saving LID techniques early in the design process and, where necessary, later consideration of several structural best management practice (BMP) options.

2. **Storm water structural control practices must be appropriate for the future land use and owner(s), thus establishing long-term on-site storm water control that is effective and manageable.**
   Maintenance and repair are critical to the long-term proper operation of the on-site storm water system. These activities are regulated by Birmingham but ultimately are the responsibility of the property owner. For this reason, the site designer must consider the appropriateness, maintenance need, and maintenance costs of any green infrastructure practices (GIPs) and BMPs being designed, in terms of both the proposed land use and future property owner(s).

3. **Site layout and on-site storm water management design should strive to utilize the natural drainage system and require as little maintenance as possible.**
   Almost all development sites contain existing natural features that can be used to help manage and mitigate storm water from impervious surfaces. Features on a development site might include natural drainage patterns, depressions, permeable soils, wetlands, floodplains, and undisturbed vegetated areas. These features can be used to reduce storm water volume, provide infiltration and storm water filtering of pollutants and sediment, recycle nutrients, and maximize on-site storage of storm water. Natural systems typically require low or no maintenance and will continue to function many years into the future. Ideally, site designers should seek to improve the effectiveness of natural systems rather than to ignore or replace them.

4. **Structural storm water practices should be implemented onsite only after all potential storm water LID techniques have been examined and chosen.**
   Meeting the required storm water performance standards on a land development will often be easier if the initial site layout of buildings, pavement, and green space is established with storm water in mind. Ideally, consideration of all LID options is done <u>before</u> the impervious surface layout is established. Economically,

operationally, and often aesthetically, the use of LID techniques offers significant benefits to developers, site designers, and post-construction property owners. Because LID techniques reduce the amount of storm water generated on a land development, materials and construction costs for land clearing, pavement, and the storm water system can be similarly reduced. After construction, a smaller storm water system and a more natural site aesthetic can easily translate to less maintenance needs and associated costs.

Figure 4-1. Dow Chemical Facility in Lake Jackson, TX *(Source: Asakura Robinson LLC)*

5. **Multi-purpose structural storm water practices that integrate well with the site's land use, purpose, and/or aesthetic are preferred over the use of single-purpose storm water practices.**

Structural storm water practices do not need to be an ugly nuisance feature on a development site placed as an afterthought. Often, practices that only have a storm water purpose can detract from the properties' aesthetic, are placed in locations that are difficult to access, and are less likely to be maintained to serve its function. With the proper site layout and design, multi-purpose storm water practices can increase a site's aesthetic and/or can increase the functional value of on-site spaces. Considering the wide range of storm water LID techniques, GIPs, and BMPs that are available, site designers can implement storm water management designs that serve multiple purposes.

6. **"One size does not fit all" in terms of storm water management solutions.**

Although the potential impacts of storm water and the need for its management are essentially the same for every land development, each site (and sometimes the watershed in which it is located) presents different challenges and opportunities when considering storm water management. For instance, a redevelopment in downtown Birmingham will likely require a much different set of storm water management solutions than a residential subdivision located on a previously undeveloped lot.

Site designers must consider the character of the property and its unique storm water opportunities or limitations and plan their site layout and storm water management designs accordingly. Attempting to apply the same techniques and practices on every site can result in storm water designs that don't fit the site or development vision, detract from the character from the area, and possibly cost more to achieve less. In contrast, thinking about each unique site as a new design and unique design can yield significant benefits. Implementation of this general design principle combined with the use of the concepts and guidance provided in this manual should result in unique, high-value storm water designs that are compliant with local regulations and are economically and aesthetically appealing.

4.2 Storm Water Quality Calculations

4.2.1 Performance Standard Summary

The calculation methods provided in this chapter are required by the *City of Birmingham Post Construction Storm Water Ordinance*. **Figure 4-2** presents the general design procedure for storm water quality protection. Flood protection requirements are not included in the figure.

The storm water quality standards, established in Chapter 3 of this manual, are summarized below:

1. **Manage the runoff volume generated by the 1.1-inch rainfall to obtain a weighted Rv ≤ 0.22 or 80% Total Suspended Solids (TSS) Removal for the applicable area.** For new developments, the applicable area is the entire development. For a redevelopment, the applicable area is the amount of impervious surface added in the post-construction condition.

2. **Generally, all impervious areas located within the applicable area must be managed for storm water quality by discharging to a GIP and/or a TSS Removal BMP prior to discharge downstream** (to subsequent flood protection controls or offsite). It is recognized that some developments will have "fringe areas", such as entry driveways, that are impracticable to manage via onsite GIPS or BMPs. The designer should eliminate such areas as much as practical. When impractical, designers should consult with the City to determine appropriate solutions.

4.2.2 Required Design Procedure

Figure 4-2, which was originally presented in Chapter 3, depicts the required design procedure for storm water quality protection. Since the use of LID techniques and GIPs is preferred, every design starts with the calculation of Rv for the applicable site area (entire area for new developments, applicable impervious area for redevelopments), and an assessment of GIP feasibility. In the figure, this is indicated in the second box from the top. This first step in the Rv Method is required for the following reasons.

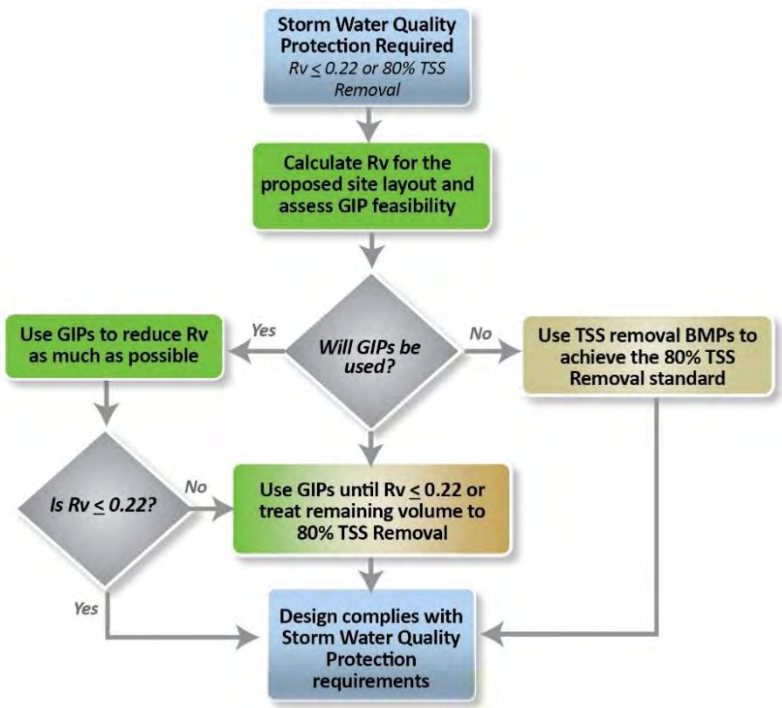
1. Calculating the site-weighted Rv allows site designers to account for the natural storm water management of the treatment volume that can be provided by green spaces located in in the development. The greater the amount of green space, the lower the Rv that is calculated. As a result, site designers can begin to reduce their treatment volume before any application of GIPs and/or BMPs simply by accounting for, and ideally maximizing, vegetated spaces on the development.

2. Assessing the feasibility of using GIPs to manage storm water is a critical step in:

   a. determining which storm water quality performance standard is most appropriate for the development; and,

   b. maximizing the use of GIPs where they are feasible on the development to reduce the treatment volume that must be managed by TSS Removal BMPs and the remaining storm water drainage system. **Even if the designer knows that the Rv Standard cannot be met on the development, every GIP used on the site provides significant headway in meeting the fall back standard of 80% TSS Removal. Therefore, the City encourages the use of GIPs whenever feasible.**

Figure 4-2. General Design Procedure for Storm Water Quality



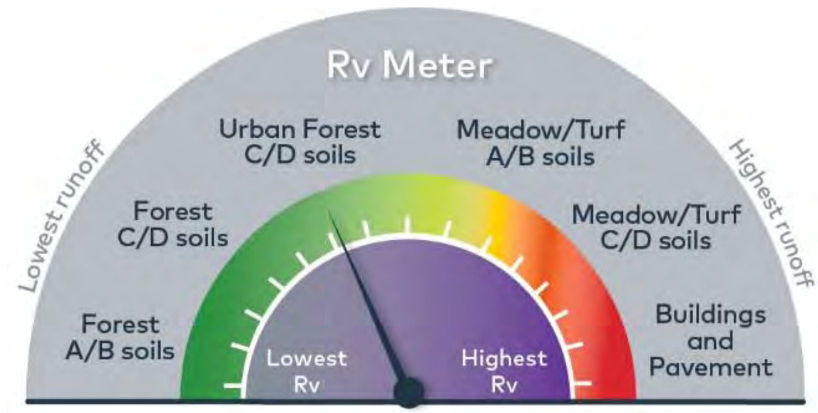
4.2.2.1 Assessing GIP Feasibility

Note that GIP feasibility is initially evaluated during the pre-concept sketch and conference (see Chapter 2). Therefore, by the time that design compliance calculations are underway, the evaluation of GIP feasibility will target only those areas of the site that showed promise of GIP feasibility during the broad level hydrologic characterization that occurred with the pre-concept sketch. In contrast, the feasibility assessment included in Figure 4-2 will entail definitive evaluations of the design parameters and criteria for the GIP(s) being considered, such as subsurface hydrologic capacity, surface area and depth requirements, slope, infiltration rate, etc.

4.2.2.2 Step 1 of Rv Method – Applied to All Sites

Calculation of the initial site-weighted Rv is required for all sites. It focuses on the basic land cover types and hydrologic soil groups that will exist in the post-construction condition. The development's land cover (buildings, pavement, and green spaces) all factor into the Rv value as indicated by **Figure 4-3** below.

Figure 4-3. Rv Meter Based on Land Cover



Forested or highly vegetated natural areas yield lower Rv values especially in native A or B soils because they can readily infiltrate and evapotranspire storm water. The Rv gets higher (and storm water runoff increases) as land cover vegetation decreases and soils become less porous and/or more compacted. Finally, the Rv is highest for impervious surfaces (buildings and pavement). Therefore, the transition of undeveloped land to a developed condition increases the Rv for a development overall. Storm water-conscious decision-making during the layout of the site's cleared areas, buildings, and pavement can mitigate this effect to some degree, thus decreasing the storm water treatment volume that must be managed by structural practices to achieve Rv $\leq$ 0.22 or 80% TSS Removal. A number of LID techniques can be used to reduce storm water generation and, thus, keep the Rv relatively low. These include, but are not limited to, keeping mature trees in pervious areas, limiting clearing and grading, maximizing vegetated spaces especially on well-draining soils, locating buildings and pavement on poorly-draining (C and D) soils, and minimizing impervious surfaces in general. See Chapter 5 for more information on LID principles and approaches.

4.2.2.3 Policies and Equations

Once the site layout is established, the site designer must identify the different land cover areas for the post-construction condition of the development using in **Table 4-1**. These areas must then be overlaid with a hydrologic soil group (HSG) map for the post-construction condition to determine the unique combinations of land cover and HSGs on the development. A single Rv value will be assigned to each land cover/HSG combination using **Table 4-2**.

An area-weighting calculation using **Equation 4-1** will determine the Rv for the calculation area (the entire new development, or the new impervious area on a redevelopment).

$$Rv = \frac{(Rv_1 \times A_1) + (Rv_2 \times A_2) + \cdots (Rv_n \times A_n)}{(A_1 + A_2 + \cdots A_n)} \qquad \textbf{Eq. 4-1}$$

Where:

Rv = the area-weighted Rv for the entire development or for the applicable area of a redevelopment

Rv_n = the Rv for a single land cover-HSG combination

A_n = the area of a single land cover-HSG combination

For redevelopments, storm water quality standards are applicable only to the amount of new impervious surface added because of redevelopment. Therefore, redevelopment projects will always start with Rv = 0.95 (the Rv value for impervious cover from Table 4-2) unless the added area includes one or more intrinsic GIPs such as a green roof or sheet flow area (see Section 4.2.3 that follows).

Table 4-1. Land Cover Types for Use with the Rv Method

Land Cover	Definition[1]
Forest[2,3,4,5]	Forests are green space areas that are undisturbed and unmaintained and meet the following minimum requirements: a. At least 1 acre in size; b. At least 120 feet wide; c. At least 90% of the land area is covered during the summer months with the foliage of mature forest trees; and d. The ground surface is comprised of forest litter and naturally- occurring understory vegetation and is undisturbed by another land use.
Urban Forest[2,3,4,5]	Urban forests are green space areas that may or may not be maintained and meet the following minimum requirements: a. At least 1 acre in size; b. At least 120 feet wide; c. At least 70% of the land area is covered during the summer months with the foliage of mature forest trees; and d. The ground surface is comprised of turf, landscaped areas, understory forest litter or other vegetation (either managed or unmanaged).
Meadow/Turf	Meadow/Turf are areas primarily covered by turf grasses and/or managed vegetation (including trees of any size, shrubs, ornamental grasses, etc.). Includes meadows, pastures, and recreational fields.
Impervious Cover	Impervious cover is any land cover material that impedes or prevents the natural infiltration of water into the soil. Examples of impervious cover include roofs, streets, driveways, parking areas, patios, sidewalks, tennis courts, solid decks, and other concrete or asphalt paved areas. Areas covered by paver blocks, gravel, "crusher stone', or other material and used as vehicle driveways, travel ways, or parking are also considered impervious cover unless the cover will be specifically designed and constructed to allow storm water infiltration. For example, permeable asphalt, concrete, and pavers are not considered impervious cover.

1 Land cover definitions apply to the proposed **post-construction** condition.

2 Bullets **a** and **b** can be disregarded for a riparian buffer area.

3 Trees must be mature and already in existence at the site when the development is proposed. Runoff Reduction Credits for reforestation are addressed in Table 4-4.

4 Multiple non-contiguous areas of forest or urban forest vegetation that are, individually, less than 1 acre in area but are located on a single development site cannot be combined to meet this definition.

5 Forest and Urban Forest cannot be used for residential lots (see Table 4-3).

Table 4-2. Runoff Coefficients for Land Cover/HSG Combinations

Land Cover	Volumetric Runoff Coefficient (Rv)				
	HSG[1] A	HSG B	HSG C	HSG D	Urban[3]
Forest[2]	0.02	0.04	0.05	0.06	0.06
Urban Forest	0.1	0.13	0.15	0.18	0.18
Meadow/Turf	0.15	0.20	0.22	0.26	0.26
Impervious	0.95				

1 HSG is an acronym for Hydrologic Soil Group.
2 Forest Rv values can also be used for certain GIPs. See Table 4-4 for more information.
3 Urban soils are defined as on-site soil having a non-agricultural, manmade surface layer that has been produced by mixing, filling, compaction, or contamination of the land surface in urban and suburban areas (adapted from Bockheim, 1974).

Example 4-1A shows how the Rv is determined for a new 10-acre development that does not use any LID approaches. **Example 4-1B** shows the Rv calculation for a 10-acre development with LID. In the example, the use of the LID practice of tree preservation to create an urban greenspace reduces the site-weighted Rv from 0.56 to 0.45.

4.2.2.4 Initial Rv Calculation for Residential Subdivisions

There are specific policies that are established for the application of Tables 4-1 and 4-2 to residential subdivision designs.

1. Forest and Urban Forest land cover cannot be used within the boundaries of individual single-family home lots for purposes of calculating the weighted Rv. Pervious land cover on individual single-family home lots must be identified as Meadow/Turf, regardless of the tree cover on the lot. The Forest and Urban Forest land covers can be used in the common and ROW areas of residential developments.

   This policy, shown in tabular form in **Table 4-3**, is applicable only to residential subdivisions for individual, detached single-family homes. It is not applicable to duplexes, triplexes or multi-family housing development (e.g., apartments, townhomes, etc.) or to commercial subdivisions.

2. Impervious land cover on individual residential lots shall be determined using the policies and procedure identified in Section 4.2.5 of this chapter.

Table 4-3. Land Cover Designation for Residential Developments

Land Cover	Land Cover Types Suitable for Rv Calculation (Residential Developments)			
	Single-Family Lots	Multi-Family Lots	Common Areas	Right-Of-Way
Forest[1]	No	Yes	Yes	Yes
Urban Forest	No	Yes	Yes	Yes
Meadow/Turf	Yes[1]	Yes[1]	Yes	Yes
Impervious Cover	Yes[2]	Yes[2]	Yes	Yes

1 The total area of **meadow/turf land cover located on single- or multi-family lots must be multiplied by 0.9** to account for potential future loss of land cover due to home renovations or additions, driveway expansions, shed or out-building construction, pool decking installations, etc.

2 The total area of **impervious land cover located on single- or multi-family lots must be multiplied by 1.1** to account for potential future increases in imperviousness due to home renovations or additions, driveway expansions, shed or out-building construction, pool decking installations, etc.

EXAMPLE 4-1A: STEP 1 FOR A TRADITIONAL SITE LAYOUT

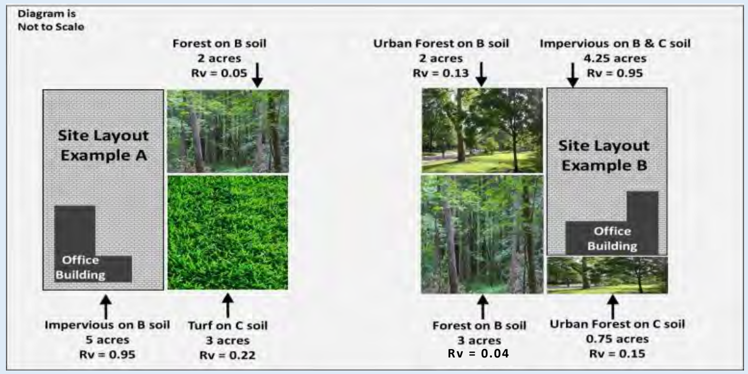
Example A: A site layout is prepared for a proposed 10-acre business development. The site layout shows that the development's land cover distribution is 5 acres of Impervious cover over B soils (Rv = 0.95), 2 acres of Forest cover over C soils (Rv = 0.05), and 3 acres of Turf grass over C soils (Rv = 0.22). Determine the development's weighted Rv using Table 4-2 and Equation 4-1.

$$\boldsymbol{Weighted\ Rv} = \frac{(\mathbf{0.95}\ \times \mathbf{5}\ \boldsymbol{ac.}) + (\mathbf{0.05}\ \times \mathbf{2}\ \boldsymbol{ac.}) + (\mathbf{0.22}\ \times \mathbf{3}\ \boldsymbol{ac.})}{(\mathbf{10}\ \boldsymbol{ac.})} = \mathbf{0.55}$$

The storm water quality performance standard of a weighted Rv ≤ 0.22 is not achieved; therefore, Intrinsic GIPs must be considered.

EXAMPLE 4-1B: STEP 1 USING LOW-IMPACT DEVELOPMENT

Example B: The proposed site layout from the 10-acre development from Example A is rearranged in order to take advantage of the site's natural storm water management properties using LID approaches. The figure below presents a comparison of the original layout (Example A) and revised layout (Example B).



In Example B, the site designer relocates the impervious cover to the area with the C soils, allowing the site's pervious land covers to be located on the moderately well-draining B soils. Instead of using Turf, the site designer maximizes the Forest land cover by increasing its coverage area from 2 acres to 3 acres and limits tree cutting in the remaining 2.75 acres to create a landscaped Urban Forest area with a managed understory area. This provides a natural, yet scenic landscape along the property's street frontage. The site designer also reduces the parking area, which allows a decrease of the impervious cover by 0.75 acres. The Urban Forest land cover is used for this pervious area behind the office building, where it will serve as a shady picnic area for the office's employees.

The resulting land cover distribution in the revised layout is 4.25 acres of Impervious cover over B soils and C soil (Rv = 0.95), 0.75 acres of Urban Forest over C soil (Rv = 0.15), 3 acres of Forest cover over B soil (Rv = 0.04), and 2 acres of Urban Forest over B soil (0.13). Determine the development's weighted Rv using Table 4-2 and Eq. 4-1.

$$\boldsymbol{Weighted\ Rv} = \frac{(\mathbf{0.95}\ \times \mathbf{4.25}\ \boldsymbol{ac.}) + (\mathbf{0.15}\ \times \mathbf{0.75}\ \boldsymbol{ac.}) + (\mathbf{0.04}\ \times \mathbf{3}\ \boldsymbol{ac.}) + (\mathbf{0.13}\ \times \mathbf{2}\ \boldsymbol{ac.})}{(\mathbf{10}\ \boldsymbol{ac.})} = \mathbf{0.45}$$

Thus, the developer's decision to use better site design principles results in a lower weighted Rv (0.45) for the site than that determined using a traditional site design (0.56). While the storm water quality performance standard of a weighted Rv ≤ 0.22 is not achieved, the extent of GIPs that must be designed and implemented to achieve the standard will be smaller due to the natural capture that occurs as a result of the LID layout.

4.2.3 The Annual Runoff Reduction Method

4.2.3.1 Compliance Procedure Summary

The use of Rv as a storm water quality standard and of Annual Runoff Reduction Method (also called the Rv Method) as a design compliance procedure are discussed in detail at the end of Chapter 3. Designers are encouraged to refer to that information for more context on the meaning of Rv and why it was selected as a preferred standard. In contrast, this chapter provides the required steps of the design compliance procedure and associated calculations.

When attempting to comply with Rv Standard, it is important to keep in mind that the following three requirements must be met.

1. Rv ≤ 0.22 must be achieved for the full treatment volume using GIPs.
2. All impervious surfaces must be managed by a GIP (see Section 4.2.1, item #2 regarding fringe areas of a site).
3. The proposed GIP(s) must capture the entire treatment volume.

Conceptually, the Rv Method includes three steps:

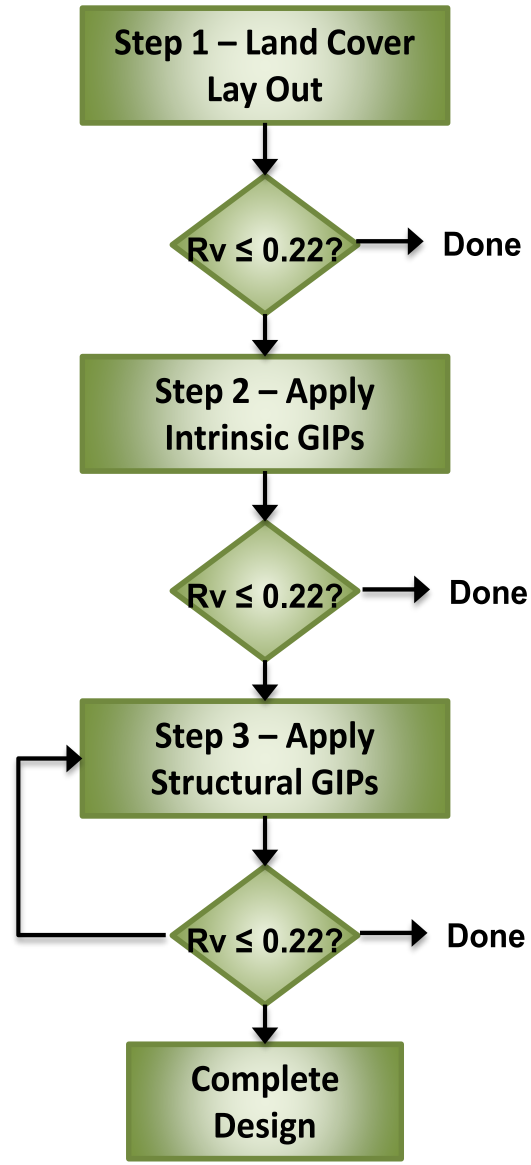
Step 1. Developing the land cover layout for the site;

Step 2. Using green spaces for intrinsic storm water management; and,

Step 3. Implementing structural green infrastructure practices (GIPs) as necessary to attain the standard.

The Rv is reduced to 0.22 or less by applying LID and GIPs as the steps progress. This process is depicted in **Figure 4-4**. Step 1 was described in Section 4.2.2. Steps 2 and 3 are summarized below. Policies and calculations are provided in the following sections.

Figure 4-4. Steps in the Rv Method



4.2.3.2 Step 2: Apply Intrinsic GIPs

Step 2 focuses on the use of intrinsic GIPs that result from the land cover layout decisions made in Step 1. Intrinsic GIPs are engineered techniques or practices that enhance the ability of pervious land cover to reduce storm water volume (see Figure 4-4). Downspout disconnection, sheet flow to pervious areas, reforestation, and green roofs are intrinsic GIPs. Each of these practices is assigned an ability to reduce 1.1 inches of rainfall in a storm event of moderate intensity, and this assignment is captured in the Runoff Reduction (RR) Credit that is assigned to the area draining to/through the GIP.

The use of intrinsic GIPs to reduce the development's Rv is not mandatory. However, site designers are strongly encouraged to consider intrinsic GIPs as a relatively "low-cost" approach to storm water volume reduction. Implementation of intrinsic GIPs requires the application of RR credits followed by recalculation of the weighted Rv for the new development (or the applicable area for redevelopments). **Equation 4-2** is used to determine the Rv for a contributing drainage area that flows through a GIP.

$$Rv_{CDA} = Rv_{Before}\left(1 - \frac{RR\ Credit}{100}\right) \qquad \textbf{Eq. 4-2}$$

Where:

Rv_{CDA} = the weighted value of Rv for contributing drainage area to the GIP after flow through the GIP

Rv_{Before} = the weighted value of Rv for contributing drainage area to the GIP before flow through the GIP

RR Credit = the RR credit from Table 4-4 (percent)

Note: Rv_{CDA} is the weighted Rv value for the contributing drainage area flowing into the GIP. If the area has multiple land cover / HSG combinations, then Rv_{Before} will be a weighted value calculated using Equation 4-1.

Table 4-4 provides the RR credits for intrinsic GIPs. The two design levels in Table 4-4 refer to specific design requirements for each intrinsic GIP. Level 2 design specifications will provide greater storm water volume reduction capabilities than Level 1 designs. Level 1 and 2 criteria are provided in detail in the GIP design specifications in Chapter 6.

Figure 4-5. Intrinsic GIP (Green Roof) at Children's Hospital in Birmingham, AL *(Source: Macknally Land Design)*

Table 4-4. Runoff Reduction Credits for Intrinsic GIPs

<table>
<tr><th colspan="2" rowspan="2">Intrinsic GIP[1]</th><th colspan="4">Runoff Reduction Credit[2] (RR Credit)</th></tr>
<tr><th colspan="2">Level 1</th><th colspan="2">Level 2</th></tr>
<tr><td colspan="2">Downspout Disconnection</td><td colspan="2">17%</td><td colspan="2">45%</td></tr>
<tr><td rowspan="2">Grass Channel</td><td>w/o compost amended soil</td><td colspan="2">1%</td><td colspan="2">20%</td></tr>
<tr><td>with compost amended soil</td><td colspan="2">12%</td><td colspan="2">30%</td></tr>
<tr><td colspan="2">Green Roof</td><td colspan="2">78%</td><td colspan="2">89%</td></tr>
<tr><td rowspan="2">Sheet Flow</td><td>to pervious area</td><td colspan="2">45%</td><td colspan="2">72%</td></tr>
<tr><td>to filter strip</td><td colspan="2">45% (with compost amended soil)</td><td colspan="2">50%</td></tr>
<tr><td rowspan="4">Reforestation[3]</td><td rowspan="2"></td><td colspan="4">Rv by Hydrologic Soil Group</td></tr>
<tr><td>D</td><td>C</td><td>B</td><td>A</td></tr>
<tr><td>w/o compost amended soil</td><td>0.18</td><td>0.15</td><td>0.13</td><td>0.10</td></tr>
<tr><td>with compost amended soil</td><td>0.06</td><td>0.05</td><td>0.04</td><td>0.02</td></tr>
</table>

1 Level 1 GIPs can be assigned a Level 2 RR Credit value if compost soil amendments are performed to increase the infiltration rate to a value equivalent to that found in an A or B soil. Other criteria to achieve a Level 2 design may also apply. See the design specification's in Chapter 6 for more information. Soil amendment information is provided in Appendix E.

2 RR Credit indicates the % rainfall volume captured by the GIP and thus removed from surface runoff.

3 The runoff reduction impact of the Reforestation GIP is not calculated using a RR Credit. It will be expressed as a Rv value for the reforested area based on the area's HSG(s)

Table 4-5 provides the applicability policies for the use of intrinsic GIPs on different land use types. These policies were developed with consideration of the difficulties in tracking, inspecting, and maintaining GIPs, especially when located on individual residential home lots. The use of intrinsic GIPs on residential lots and privately-owned roadways is limited; however, their use in residential common areas is encouraged. In addition, site designers should also consider the use of LID practices to maximize the use of forest and urban forest land cover types in residential common areas. See Chapter 5 for LID guidance. **Example 4-2** shows how intrinsic GIPs are applied on a storm water management design.

Table 4-5. Land Use Applicability Policies for Intrinsic GIPs

Intrinsic GIP	Development Land Use Type				
	Reside-ntial Lots	Residential Common Areas	Private Road-ways	Public Roadways and ROW	All Other Land Uses
Downspout Disconnection	⟐	●	⦸	⦸	●
Grass Channel	●	●	⟐	⦸	●
Green Roof	⟐	●	⦸	⦸	●
Reforestation	⟐	●	⟐	⦸	●
Sheet Flow	⟐	●	●	⦸	●

Key:
- ● The GIP is acceptable for the land use type. Site designs including this GIP may be approved depending upon the GIP's suitability for the specific development and whether the design is in accordance with all other local ordinances, codes, policies, and technical specifications.
- ⦸ The GIP is not acceptable for the land use type.
- ⟐ The GIP is allowed for the land use type, but it cannot be used to meet the Rv Standard or included in storm water quality calculations.

EXAMPLE 4-2: STEP 2 USING INTRINSIC GIPS

The LID site layout from Example 4-1B is proposed for a 10-acre office development. The layout is 4.25 acres of Impervious cover over B soils and C soils, 0.75 acres of Urban Forest over C soil, 3 acres of Forest cover over B soils, and 2 acres of Urban Forest over B soils. After LID, the site-weighted Rv is 0.45. The site designer now considers the use of Intrinsic GIPs. A portion (0.75 acres) of the development's parking area can drain (using a level spreader) via a Level 2 sheet flow GIP to the urban forest area (B soil). As well, approximately 0.75 acres of roof discharge can drain into the other urban forest area using Level 1 downspout disconnection GIP. Using Equation 4-2, determine two Rv_{CDA} values for the sheet flow and downspout disconnection Intrinsic GIPs, and then determine the development's weighted Rv after application of the Intrinsic GIPs.

First, the Rv_{CDA} is determined for the 0.75-acre parking area discharging via sheet flow (SF) over B soil area using Equation 4-2. From Table 4-2, Rv_{Before} = 0.95, and the RR credit for a Level 2 sheet flow design is 50%, from Table 4-4.

$$\mathbf{Rv_{CDA(SF)} = 0.95\,(1 - 0.50) = 0.48}$$

Thus, the Rv for the parking area that is managed via sheet flow is reduced from 0.95 to 0.48. A similar calculation is performed to determine the Rv for the roof contributing drainage area to the Level 1 downspout disconnection to C soil design ($Rv_{CDA(DS)}$). Rv_{Before} = 0.95 and the Runoff Reduction Credit = 17%.

$$\mathbf{Rv_{CDA(DD)} = 0.95\,(1 - 0.17) = 0.79}$$

Now the development's new weighted Rv can be determined with the consideration of the runoff reduction provided by the Intrinsic GIPs. With the GIPs in place, the site layout is as follows:

- 0.75 acres of parking area discharged to a Level 2 Sheet Flow GIP, Rv_{CDA} = 0.48;
- 0.75 acres of rooftop discharged to a Level 1 Downspout Disconnection GIP, Rv_{CDA} = 0.79;
- 2.75 acres of impervious area (remaining rooftop, parking and driveway), Rv = 0.95;
- 3 acres of Forest cover over B soil; and, Rv = 0.04;
- 0.75 acres of Urban Forest cover over C soil, Rv = 0.15;
- 2 acres of Urban Forest cover over B soil, Rv = 0.13

$$\mathbf{Weighted\ Rv = \frac{(0.48 \times 0.75ac) + (0.79 \times 0.75ac) + (0.95 \times 2.75ac) + (0.04 \times 3ac) + (0.15 \times 0.75ac) + (0.13 \times 2ac)}{(10\ ac)}}$$

$$\mathbf{Weighted\ Rv = 0.40}$$

The application of Intrinsic GIPs uses the natural runoff reduction characteristics of the site to decrease the weighted Rv from 0.45 to 0.40. Using relatively low cost and low maintenance Intrinsic GIPs, progress has been made toward meeting the storm water quality performance standard of a weighted Rv ≤ 0.22. However, the performance standard still has not been achieved. Structural GIPs must be designed to further reduce the weighted Rv.

4.2.3.3 Step 3: Apply Structural GIPs

Structural GIPs are controls that are designed and constructed to infiltrate, evapotranspire, or harvest and use rainfall and storm water within the GIP itself. Examples include infiltration trenches, bioretention, permeable pavement, and cisterns. Both intrinsic and structural GIPs should be considered for a development if feasible, regardless of which storm water quality performance standard has been selected. Every GIP used on a development provides significant headway in meeting either storm water quality standard, and GIPs provide volume reduction that can reduce the need for, or size of, other storm water system components. Therefore, the City encourages the use of GIPs whenever feasible.

If the designer has selected the Rv Standard for storm water quality control and a Rv ≤ 0.22 has not been achieved after initial GIP design using Step 3, then additional structural GIPs must be designed until the Rv Standard is met or exceeded, or the designer must treat the remaining volume to the 80% Removal Standard.

Design and sizing specifications have been created for each of these GIPs to account for the RR credit assigned to the area draining to it. Design specifications for GIPs are provided in Chapter 6.

The determination of a development's weighted Rv after application of structural GIPs is exactly the same as that used for intrinsic GIPs. Each GIP is assigned a RR Credit that is applied to the contributing drainage area of the BMP using Equation 4-2. Then, the weighted Rv for the development (or in the case of redevelopment, the applicable area) is recalculated. **Table 4-6** lists the GIPs and the assigned credits for each. The two levels represent a baseline design (Level 1) and a more expansive design (Level 2) that can achieve a greater degree of runoff reduction, and hence, pollution removal. This distinction is important because performance can vary greatly depending on sizing and design features. The site designer can choose which design level is most appropriate to the development's needs. Level 1 and Level 2 design specifications are provided in Chapter 6.

Table 4-6. Runoff Reduction Credits for Structural GIPs

Structural GIP	Runoff Reduction Credit (RR Credit)	
	Level 1	Level 2
Bioretention[1]	56%	78%
Urban Bioretention[1]	56%	Not Applicable
Permeable Pavement	39%	72%
Infiltration Trench[1]	45%	89%
Water Quality Swale[1]	34%	56%
Cisterns	Design Dependent – See Chapter 6	
Detention (ED or standard)[2]	6%	Not Applicable

1 These structural GIPs typically occupy a portion of the land area within the development and can infiltrate (and in some cases evapotranspirate) the rain that falls on them. For this reason, the land area occupied by these GIPs can be assigned the Forest cover Rv value (Table 4-2) for their underlying HSG.

2 Detention ponds, whether in a standard or extended detention (ED) configuration, are popular BMPs for the multiple primary purposes of TSS Removal and flood protection. Thus, detention ponds are not typically protected or managed to preserve infiltration and, therefore, should not be considered as a first-choice practice for runoff reduction purposes. However, it is recognized that detention ponds can provide some limited infiltration, as indicated in the table. The design specifications for detention ponds are provided in the TSS Removal BMP Design Specification sheets, which are provided in Chapter 6.

Table 4-7 provides the land use applicability policies for the structural GIPs included in Chapter 6. These policies have been developed based on the suitability of intrinsic GIPs for different types of land uses and any inherent difficulties in tracking, inspecting, and maintaining the GIPs, especially when located on individual residential lots.

Table 4-7. Land Use Applicability Policies for Structural GIPs

Structural GIP	Land Use Type				
	Residen-tial Lots	Residen-tial Common Areas	Private Roadway	Public Roadwa and ROW	All Other Land Uses
Cistern	◈	◈	⦸	⦸	●
Urban Bioretention	⦸	●	●	⦸	●
Permeable Pavement	◈	●	●	⦸	●
Dry Water Quality Swale	⦸	●	●	⦸	●
Infiltration Trench	⦸	●	●	⦸	●
Bioretention	◈	●	●	⦸	●
Extended Detention	●	●	●	⦸	●

Key:
- ● The GIP is generally allowed for the land use type. Site designs including this GIP may be approved depending upon the GIP's suitability for the specific development and whether the design is in accordance with all other local ordinances, codes, policies and technical specifications.
- ⦸ The GIP is not allowed for the land use type.
- ◈ The GIP is allowed for the land use type, but it cannot be used to meet the Rv Standard or included in storm water quality calculations.

As indicated by Table 4-7, the use of these GIPs on residential lots for purposes of compliance with the Rv Standard is generally not allowed. However, site designers of residential developments are encouraged to consider these practices for common areas where their long-term operation and maintenance is better assured. The use of LID practices to maximize the use of Forest and Urban Forest land cover types in residential common areas is also recommended. Chapter 5 has information on LID techniques.

Site Design Tip

Mixing GIPs to Maximize Effectiveness

GIPs are often most effective when they are designed as multiple, small, decentralized facilities that are located in a number of locations within a development. When using multiple GIPs, site designers can often save time and money by mixing BMP design levels to meet the needs of the performance standard. Level 1 GIPs may be sufficient in developments with relatively low imperviousness, while Level 2 GIPs might be necessary to meet the performance standard in a highly impervious site. Regardless, a site's need for Level 1 or Level 2 GIPs can easily be "tested" prior to full-scale GIP sizing and design by performing trial calculations using Equations 4-1 and 4-2 and the appropriate RR Credits from Tables 4-4 and 4-6.

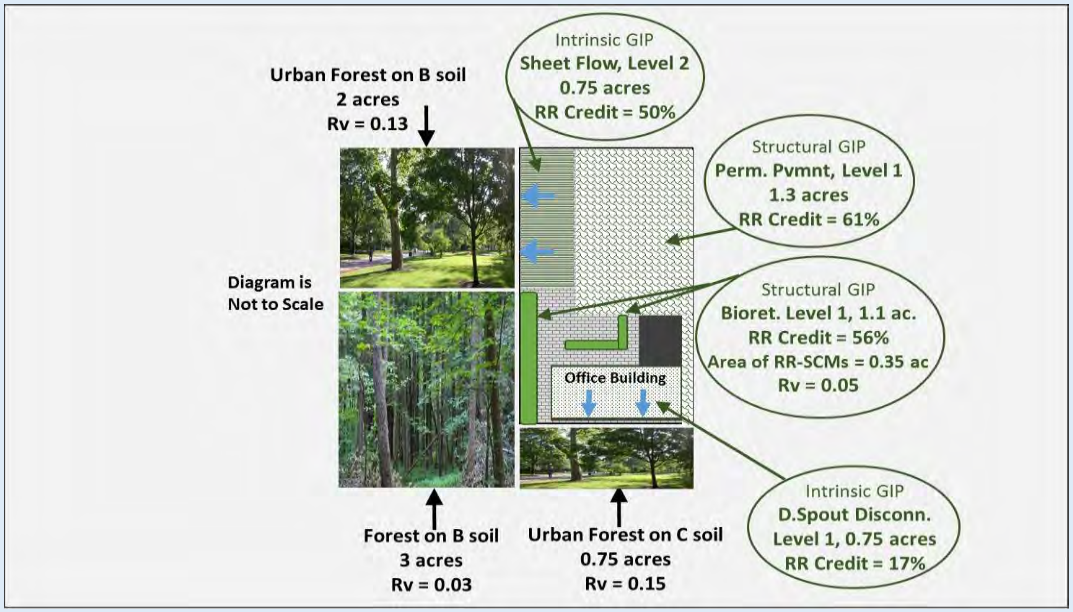
Photo: Example of GIPs used in series. The bioretention area is located within a pervious concrete parking area.

Courtesy: City of Chattanooga TN

EXAMPLE 4-3: STEP 3 USING GREEN INFRASTRUCTURE PRACTICES

This expands on Example 4-2 and presents calculations for Structural GIPs to finish the design. Continuing with Example 4-2, the LID site layout with Intrinsic GIPs for a 10-acre business development results in a weighted Rv = 0.40. To meet the storm water quality performance standard, the weighted Rv for the development must be less than or equal to 0.22. Apply structural GIPs and to reduce weighted Rv to achieve the performance standard.

The site designer decides to use permeable pavers for the driveway, a portion of the parking area, and side alley, resulting in 1.3 acres of permeable paver area. The permeable paver area does not receive drainage from any other areas of the site. Several bioretention GIPs will be used to manage the runoff from the remaining impervious area (connected rooftop, parking in front of the building, and the rear alley). These facilities will be located on C soils around the end of the building. The total surface area of the bioretention will amount to 0.35 acres, and these areas will control runoff from 1.1 acres of impervious surface. The new site layout with both the intrinsic and structural GIPs is shown in the graphic below.



First, the designer attempts to meet the storm water quality performance standard using Level 1 GIP designs. The RR credit calculation for the bioretention area is first. For the 1.1-acre area discharging to the Level 1 bioretention areas: Rv_{Before} = 0.95 and the RR Credit = 56%, from Table 4-6.

$$\mathbf{Rv_{CDA(Bio)} = 0.95\,(1 - 0.56) = 0.42}$$

Second, Table 4-6 (footnote 1) indicates that the 0.35 acres of bioretention can be assigned a Rv for Forest on C soil, Rv = 0.05.

Now the development's new weighted Rv can be determined with the consideration of the runoff reduction provided by the Structural GIPs.

This example is continued on the next page.

EXAMPLE 4-3: CONTINUED

For the 1.3-acre area of the Level 1 permeable pavers, Rv_{Before} = 0.95 and the RR credit = 39%, from Table 4-6. Applying Equation 4-2:

$$\mathbf{Rv_{CDA(PP)} = 0.95\ (1 - 0.39) = 0.57}$$

Now the development's new weighted Rv can be determined with the consideration of the runoff reduction provided by the GIPs.

The site layout is now as follows:

- 1.1 acres of impervious surface discharged to a Level 1 Bioretention GIP, $Rv_{CDA(Bio)}$ = 0.42;
- 0.35 acres of Bioretention area over C soil, Rv = 0.05
- 1.3 acres of Level 1 Permeable Pavement GIP, $Rv_{CDA(PP)}$ = 0.57;
- 0.75 acres of parking area discharged to a Level 2 Sheet Flow GIP, Rv_{CDA} = 0.48;
- 0.75 acres of rooftop discharged to a Level 1 Downspout Disconnection GIP, RvCDA = 0.79;
- 3 acres of Forest cover over B soil; and, Rv = 0.04;
- 0.75 acres of Urban Forest cover over C soil, Rv = 0.15;
- 2 acres of Urban Forest cover over B soil, Rv = 0.13

$$\text{Weighted Rv} = \frac{(0.42 \times 1.1ac) + (0.05 \times 0.35ac) + (0.57 \times 1.3ac) + (0.48 \times 0.75ac) + (0.79 \times 0.75ac) + (0.04 \times 3ac) + (0.15 \times 0.75ac) + (0.13 \times 2ac)}{(10\text{ ac})}$$

$$\mathbf{Weighted\ Rv = 0.26}$$

With a weighted Rv = 0.26, the application of Level 1 Structural GIPs allows the runoff reduction characteristics of the site to decrease but not sufficiently to meet the storm water quality performance standard of a weighted Rv ≤ 0.22. Next, the site designer tests the use of a Level 2 design for the bioretention and permeable pavement GIPs, Level 2 RR Credit of 78% and 72% respectively from Table 4-6. Again, applying Equation 4-2:

$$\mathbf{Rv_{CDA(Bio)} = 0.95\ (1 - 0.78) = 0.21} \qquad \mathbf{Rv_{CDA(PP)} = 0.95\ (1 - 0.72) = 0.27}$$

Reapplying Equation 4-1,

$$\text{Weighted Rv} = \frac{(0.21 \times 1.1ac) + (0.05 \times 0.35ac) + (0.27 \times 1.3ac) + (0.48 \times 0.75ac) + (0.79 \times 0.75ac) + (0.04 \times 3ac) + (0.15 \times 0.75ac) + (0.13 \times 2ac)}{(10\text{ ac})}$$

$$\mathbf{Weighted\ Rv = 0.20}$$

Using Level 2 bioretention and permeable pavement GIPs will allow the site to have a weighted Rv = 0.20, which is less than the required performance standard. The site designer checks again that all impervious areas are managed using storm water quality protection using GIPs and that required treatment volumes can be captured by the GIPs (not shown in this example). Upon positive confirmation of these checks, the designer can be confident their design will meet the storm water quality performance standard in Birmingham.

4.2.3.4 Special Case: GIPs in Series

Using GIPs in series can provide the site designer with tremendous flexibility in evaluating the most effective approach to meet one of the storm water quality performance standards. However, the calculation of the volume removal percentage for controls in series can be complex, and it is dependent upon the type of GIP being considered. When GIPs are placed in series, the upstream control has the advantage of initially handling runoff from the many small storms, while the downstream GIP must be able to handle the overflow from the first GIP (i.e., a set of fewer, but larger storms). Therefore, the ability to capture immediate volumes and store them for later removal is critical for the downstream BMP. When placing GIPs in series, any GIP can be used as the upstream control, but downstream GIPs are limited to:

- Bioretention
- Urban Bioretention Areas
- Permeable Pavement
- Infiltration Trench
- Water Quality Swale
- Detention
- Cisterns

Equation 4-3 must be used to calculate the Rv for the contributing drainage area (CDA) to GIPs placed in series. Note that credit will be given for no more than two controls used in series.

$$Rv_{CDA\,S} = Rv_{CDA}\left[(1 - RR\ Credit_1) \times (1 - RR\ Credit_2)\right] \quad \textbf{Eq. 4-3}$$

Where:

$Rv_{CDA\,S}$ = the weighted Rv for contributing drainage area(s) to the GIPs placed in series after flow through the GIPs

Rv_{CDA} = the weighted Rv for the CDA(s) to the upstream GIP before flow through the GIP

RR $Credit_1$ = the Runoff Reduction percentage for the ***upstream*** GIP, defined from Table 4-4 or Table 4-6

RR $Credit_2$ = the Runoff Reduction Credit percentage for the ***downstream*** GIP, defined in Table 4-6

Example calculations for GIPs in series are provided after the next section in **Example 4-4**.

4.2.4 Calculating the Treatment Volume - Sizing Media-Based GIPs

This section presents the method that must be used to determine the treatment volume for media-based GIPs and, thus, size the GIPs. Treatment volume calculation for non-media-based GIPs is provided in the design specifications for the GIPs provided in Chapter 6. Note that the "treatment volume" discussed herein is the volume of storm water that will be managed by the GIP for the CDA that discharges to that GIP.

Equations 4-4 and 4-5 are the general equations that must be used to determine the GIP treatment volume (Tv_{GIP}). Example 4-4 also indicates how these two equations are used.

$$Tv_{GIP} = Mult.\left[(P(Rv)\,(CDA))\left(\frac{43{,}560\ ft^2}{1\ ac}\right)\left(\frac{1\ ft}{12\ in}\right)\right] \quad \textbf{Eq. 4-4}$$

$$Tv_{GIP} = n(D)(SA) \quad \textbf{Eq. 4-5}$$

Where:

Tv_{GIP}	=	the GIP treatment volume (in cubic feet)
Mult.	=	the multiplier for the GIP from Table 4-8
P	=	rainfall depth, 1.1 inches
Rv	=	the weighted Rv for the contributing drainage area to the GIP without consideration of GIPs located within the CDA[1]
CDA	=	the contributing drainage area to the GIP (in acres)
n	=	porosity of the media
D	=	media depth of the GIP (in feet)
SA	=	surface area of the GIP (in square feet)
n(D)	=	the equivalent storage depth (D_E) for multi-media GIPs

Equation 4-4 includes a multiplier (Mult.), which is required for the design of some GIPs, especially Level 2 designs. BMP multipliers are provided in **Table 4-8** and in the design specifications in Chapter 6.

Table 4-8. BMP Multipliers for Use in Equation 4-4

GIP	Multiplier	
	Level 1	Level 2
Bioretention	1	1.25
Urban Bioretention	1	not applicable
Permeable Pavement	1	1.1
Infiltration Trench	1	1.1
Water Quality Swale	1	1.1
Detention	1.25	not applicable

Equation 4-6 must be used to find the equivalent storage depth (D_E) for media-based BMPs with multiple layers of media, which is used in calculation of Tv_{GIP}.

$$D_E = n_1(D_1) + \ n_2(D_2) + \cdots \qquad \textbf{Eq. 4-6}$$

Where:

D_E	=	the equivalent storage depth
n_x	=	the porosity the 1st layer, 2nd layer, etc. (Table 4-9)
D_x	=	the depth of media in the 1st layer, 2nd layer, etc.

Table 4-9 provides basic specifications for porosity and field capacity for the standard recommended soil-based media and gravel for GIPs. Additional GIP design specifications are provided in Chapter 6.

Table 4-9. Volume-Based Specifications for GIP Media

Parameter	Value	
	Porosity	Field Capacity
Soil-Based Media[1]	0.40	0.25
Gravel[2]	0.40	0.04
Ponding	1.0	not applicable

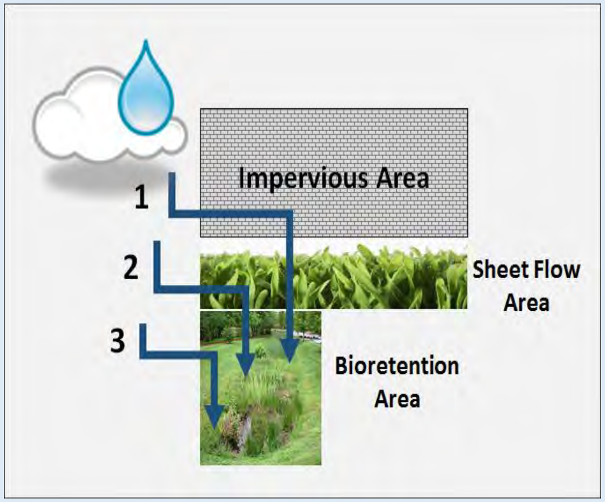
1 For soil-based media in bioretention, water quality swales and tree planter boxes.

2 For gravel-based media in bioretention and urban bioretention areas, water quality swales, permeable pavement, and infiltration trenches.

---

[1] Note: Tv_{GIP} must be calculated for the volume of runoff from 1.1 inches of rainfall that will be discharged to the GIP from its' contributing drainage area. Therefore, when using Equation 4-4 to calculate Tv_{GIP} for a solitary BMP, RR Credits (from Table 4-6) cannot be applied in the calculation of the weighted Rv. **When using the equation to calculate Tv_{GIP} for BMPs in** series, the weighted Rv can include consideration of the RR Credit that is provided by the upstream BMP. The resulting Tv_{GIP} is then applicable to the treatment volume that will be required for the downstream BMP.

EXAMPLE 4-4: GIPS IN SERIES, GIP SIZING



A site designer will be using a mix of Intrinsic GIPs and Structural GIPs to manage storm water discharges from a 0.5-acre impervious area (Rv = 0.95). The impervious area is first disconnected via Sheet Flow (an Intrinsic GIP, Level 2), through a 0.25-acre turf area on C soil (Rv = 0.22). The sheet flow area has a RR Credit of 72%. Storm water from the sheet flow area will then discharge to a 0.06-acre bioretention facility constructed in C soil (Rv = 0.22). The bioretention facility will have a Level 2 design and, therefore, has a RR Credit of 78%. The figure provides a basic schematic of the situation. Note that the only the runoff generated by the impervious area (denoted by the blue line labeled "1") is being managed by GIPs placed in series. **Determine the Rv for each of the three areas, the weighted Rv for the total area, then determine the surface area of the bioretention GIP.**

The Rv for the Impervious Area after flow through both GIPs is calculated using Equation 4-3.

$$\mathrm{Rv}_{\mathrm{CDA(Imp)}} = 0.95\ [(1-0.72)(1-0.78)] = 0.06$$

Thus, the effective Rv of the GIPs in series becomes 0.06. Now calculate the weighted Rv for the entire site. The Rv for the bioretention GIP area is 0.05 (Forest Cover on C soil per footnote 1 of Table 4-6). The Rv for the Sheet Flow area after flow through the bioretention GIP is calculated using Equation 4-2.

$$\mathrm{Rv}_{\mathrm{CDA(SF)}} = 0.22(1-0.72) = 0.06 \qquad \mathrm{Rv}_{\mathrm{CDA(SF,Bio)}} = 0.06(1-0.78) = 0.01$$

Finally, the weighted Rv for the entire area (after flow through the bioretention GIP) is found using Equation 4-1.

$$\mathbf{Weighted\ Rv} = \frac{(\mathbf{0.06 \times 0.5\ ac}) + (\mathbf{0.01 \times 0.25\ ac}) + (\mathbf{0.05 \times 0.06\ ac})}{(\mathbf{0.81\ ac})} = \mathbf{0.04}$$

To size the bioretention GIP, first calculate the weighted Rv for the bioretention GIP's contributing drainage area (excluding the GIP itself) using Equation 4-1.

$$\text{Weighted } \mathrm{Rv}_{CDA} = \frac{(0.95 \times 0.5\ \mathrm{ac}) + (0.06 \times 0.25\ \mathrm{ac})}{(0.75\ \mathrm{ac})} = 0.65$$

After applying a Level 2 bioretention GIP (RR Credit =78%), the resulting $\mathrm{Rv}_{\mathrm{CDA}}$ = 0.14. To size the GIP, consult Table 4-8 and the design specification for the bioretention GIP in Chapter 6. The multiplier for a Level 2 bioretention BMP design volume ($\mathrm{Tv}_{\mathrm{GIP}}$) is 1.25, the media depth (D) must be no less than 36-inches (3 ft), and the maximum ponding depth is 6-inches (0.5 ft). Using Table 4-9, the porosity (n) for soil-based media is 0.4 and for ponding is 1.0. Use Equation 4-6 to calculate the Equivalent Storage Depth ($\mathrm{D_E}$).

$$\mathbf{D_E = 0.4\ (3\ ft) + 1.0\ (0.5\ ft)\ =\ 1.7\ ft}$$

The Surface Area (SA) can be determined by application of Equations 4-4 and 4-5 and solving for SA. Note that the equivalent depth ($\mathrm{D_E}$) is substituted for n(D) and rainfall depth of 1.1 inches (for Birmingham).

$$\mathrm{Tv_{GIP}} = 1.25\ (1.1\ \mathrm{in})(0.75\mathrm{ac})(0.65)\left(\frac{43560\ \mathrm{ft}^2}{1\ \mathrm{ac}}\right)\left(\frac{1\ \mathrm{ft}}{12\ \mathrm{in}}\right) = \mathrm{n(D)(SA)}$$

$$\mathbf{Tv_{GIP} = 2,433\ ft^3 = D_E(SA)}$$

$$\mathbf{\frac{2,433\ ft^3}{1.7\ ft} = 1,431\ ft^2 = SA}$$

4.2.5 Eligibility for Performance Standard Credits or Reductions by Development Type

Certain development types that inherently constitute a storm water LID approach may be eligible for a Rv Standard Credit. Eligibility and application requirements are below.

1. **Eligibility criteria.** To be eligible for a treatment volume adjustment, the proposed development shall conform to at least one of the following criteria and shall not have any of the countermanding conditions.

   a. **Cluster Development**, defined per *Title 2-Zoning Ordinance Chapter 3 District Area and Dimensional Regulations Article II. Conservation Subdivision and Cottage Development*. For example, lots may be reduced in area the equivalent of one smaller zone districts, except that no single-family lot shall be less than 3,500 square feet. To receive the Rv Standard Credit, the TSS Removal Standard cannot be applied and all storm water treatment must be performed using GIPs. Therefore, the cluster development must attain a Rv ≤ 0.26 for the 1.1-inch rainfall.

   b. **Vertical Density Development**, defined as a new development or redevelopment that has a floor to area ratio of at least 2 or at least 18 units per acre. Refer to *Title 2-Zoning Ordinance Chapter 1: Zoning Districts* for vertical density requirements. A parking garage is an example of a development that could receive this credit. To receive the Rv Standard Credit, the TSS Removal Standard cannot be applied and all storm water treatment must be performed using GIPs. Therefore, the vertical development must attain a Rv ≤ 0.26 for the 1.1-inch rainfall.

   c. **Brownfield Redevelopment**, defined as a redevelopment of a property where the presence of a hazardous substance, pollutant, or contaminant is known or suspected. To receive the Rv Standard Credit, the redevelopment must reforest an area on-site that is equal to or greater than the amount of impervious area proposed to be added for redevelopment. If this is done, the added reforested area can be included in the initial Rv calculation for the redevelopment, thus greatly reducing the starting Rv for the added impervious area. Ultimately, this Rv reduction will reduce the treatment needed to achieve the standard of Rv ≤ 0.22 or 80% TSS Removal for the added impervious area. Note that infiltration is prohibited where existing soil contamination is present in areas that are, or could be, subject to contact with infiltrated storm water, therefore 80% TSS Removal BMPs are allowed when this credit is applied.

2. **Countermanding conditions:** The following circumstances may eliminate eligibility to apply treatment volume reductions.

   a. The development discharges storm water, either directly or through a public or private storm water drainage system, to a stream that has an established Total Maximum Daily Load (TMDL) or is subject to state or federal water quality requirements or designations.

   b. A storm water or watershed master plan or engineering study indicates that controls are needed to limit the adverse impacts of polluted storm water discharges from development.

   c. The property has a history of hazardous substances, pollutants, or contaminants that will, in the judgement of the Director, be better managed with full storm water management controls.

4.2.6 Curve Number Adjustments

The capture of storm water by structural GIPs changes the runoff depth entering downstream detention structures that are designed for peak discharge and flood control. As a result, the lower depth can be considered when sizing detention structures on developments that implement GIPs. This is done by adjusting the curve number (CN) for the development. The adjusted curve number can be used for all return period events required for detention sizing.

Note: The reduction of detention requirements can be considered only if structural GIPs will be used at a development. This reduction does not apply to sites that employ only LID or Intrinsic GIPs to address runoff reduction. The impact of LID and pervious area land uses associated with Intrinsic GIPs on peak discharge calculations is already inherently included in the determination of a CN.

An approximate approach to account for the impact of the GIPs on runoff volumes is to adjust the CN for the post-developed conditions off site. The adjusted curve number (CN_{adj}) can then be used in hydrologic calculations and in routing. The standard SCS rainfall-runoff equation in **Equations 4-7a** and **7b** below provides a way to calculate a total runoff. **Table 4-10** is used for the precipitation parameter (P).

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \qquad S = \frac{1000}{CN} - 10$$ **Eqs. 4-7a and 4-7b**

Where:

Q	=	the accumulated direct runoff (inches), for P greater than Ia = 0.2S.
P	=	the accumulated rainfall depth (inches) for the 24-hr design storm (see Table 4-10)
S	=	the potential maximum soil retention (inches)
CN	=	the SCS Curve Number

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 BMP (Tv_{GIP}) from Equations 4-4 and 4-5) expressed in watershed inches.

Table 4-10. Birmingham 24-Hour Rainfall Depths

Return Period (Years)	Rainfall Depth (inches)
1	3.63
2	4.1
10	5.83
25	7.14
100	9.49

Equation 4-8 is used to make the initial adjustment by determining the adjusted total Runoff (Qadj).

$$Q_{adj} = Q - \frac{12(Tv_{GIP})}{43560(CDA)}$$ **Eq. 4-8**

Where:

Q_{adj}	=	the accumulated direct runoff adjusted for the volume removed by GIPs (inches)
Q	=	the accumulated direct runoff from Equation 4-7a (inches)
Tv_{GIP}	=	the GIP design volume (cubic feet)
CDA	=	the contributing drainage area (acres)

Equation 4-9 then calculates the modified curve number (CN_{adj}) based on Q_{adj}.

$$CN_{adj} = \frac{1000}{10 + 5P + 10(Q_{adj}) - 10(Q_{adj}^2 + 1.25Q_{adj}P)^{\frac{1}{2}}}$$ **Eq. 4-9**

Where:

CN_{adj} = the adjusted curve number for the development

Q_{adj} = the accumulated direct runoff adjusted for the volume removed by GIPs

P = the accumulated rainfall depth (inches) for the 24-hr design storm (see Table 4-10)

Example 4-5 provides a curve number adjustment calculation.

4.2.7 Multi-Benefit GIP Incentives

This section identifies how the incentives available with Multi-Benefit GIPs are used and provides policies for their application during the design of a development. The incentives are applied in the design calculations for the Rv Method. Further discussion on the rationale behind Multi-Benefit GIPs is provided in Chapter 3.

Table 4-11 lists the incentives and establishes the eligibility and application criteria for each incentive.

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EXAMPLE 4-5: ADJUSTING THE CURVE NUMBER

A proposed site design includes a 1.5-acre parking lot that will drain into the site's detention pond. The detention pond must be designed for the 25-yr, 24-hr storm event. A bioretention GIP is used at the downstream end of the parking lot. Determine CN_{adj} for the site to account for the volume captured by the GIP. Note: Prior to adjustment, the SCS CN for the parking lot is 98.

Step 1. Calculate the Total Runoff (Q): From Table 4-10, P is 7.14 inches (25-year storm). Use Equations 4-7a, 7b.

$$S = \frac{1000}{98} - 10 = 0.2 \quad then \quad Q = \frac{(7.14 - 0.2(0.2))^2}{(7.14 + 0.8(0.2))} = 6.90\ in.$$

Step 2. Calculate bioretention design volume (Tv_{GIP}): Use Equation 4-4 to determine Tv_{GIP}. Rv = 0.95 (Table 4-2), Mult. = 1.25 (Table 4-8), P = 1.1 inches and CDA = 1.5 acres.

$$Tv_{GIP} = (1.25)1.1\ \text{in}(1.5\text{ac})(0.95)\frac{43{,}560\ \text{ft}^2}{1\text{ac}}\left(\frac{1\ \text{ft}}{12\ \text{in}}\right) = 7{,}113\ \text{ft}^3$$

Step 3. Calculate the adjusted total runoff (Qadj): Use Equation 4-8 to determine Q_{adj}.

$$\boldsymbol{Q_{adj} = 6.90\ in - \frac{12(7,113 ft^3)}{(43,560)(1.5ac)} = 5.59\ in}$$

Step 4. Calculate the adjusted curve number (CNadj): Use Equation 4-9 to determine CN_{adj}. P = 7.14 inches

$$CN_{adj} = \frac{1000}{10 + 5(7.14) + 10(5.59) - 10(5.59^2 + 1.25(5.59)7.14)^{1/2}}$$

$$CN_{adj} = 86.7$$

The site designer can perform a check by substituting CN_{adj} into Equation 4-7(b) to obtain S, and then using Equation 4-7(a) to calculate Q_{check}. Note that P in Equation 4-7(a) is the 24-hour design storm used (7.14 inches in this case).

$$S = \frac{1000}{86.7} - 10 = 1.53 \quad then, \quad Q_{check} = \frac{(7.14 - 0.2(1.53))^2}{(7.14 + 0.8(1.53))} = 5.59\ in.$$

$Q_{check} = Q_{adj}$; therefore, the adjusted curve number is correct.

Table 4-11. Multi-Benefit GIP Incentives & Eligibility Criteria

GIP Incentive	Eligibility Criteria	Application Criteria
Use of the Site Reforestation GIP or Stream Buffer Preservation GIP	Site reforestation refers to the planting of trees, shrubs, and other native vegetation in previously disturbed areas to ***permanently*** restore them to a forest land cover. Eligibility requires the ***permanent preservation and protection*** of the reforestation area, such that vegetation will not be disturbed or removed in the future. The GIP shall be designed and installed in accordance with this manual. See also Chapter 5, Section 5.4.5. *This incentive may not be combined with the Soil Restoration GIP incentive defined in this table for the same area.*	**Rv criterion:** Subtract 50% of any permanently protected reforested areas from the total site area when calculating the GIP treatment volume (Tv_{GIP}) for the development. If soil restoration is performed in the reforested areas, then the 100% of the reforested areas can be subtracted. **TSS Removal criterion:** Subtract 50% of any permanently protected reforested areas from the total site area when calculating the TSS treatment volume (Tv_{TSS}) for the development. 100% of the reforested areas can be subtracted if soil restoration is performed in the reforested areas. **Qp criterion:** The post-development hydrologic condition of any permanently protected reforested areas are equivalent to those of a similar cover type (e.g., meadow, brush, woods) in FAIR condition. If soil restoration is performed in the reforested areas, then the post-development hydrologic condition of the reforested areas is equivalent to that of a similar cover type in GOOD condition.
Use of the Soil Restoration GIP	Soil restoration is the process of tilling and adding compost and other amendments to previously compacted or disturbed soils or fill to restore infiltration and percolation to that of a well-drained soil. Eligibility requires the ***permanent protection*** of the soil restoration area to maintain well-draining properties. The GIP shall be designed and installed in accordance with this manual. *This incentive may not be combined with the Site Restoration GIP incentive defined in this table for the same area.*	**Rv or TSS Removal criterion:** Subtract 50% of any permanently protected soil restoration areas from the total site area when calculating the GIP or TSS treatment volume (Tv_{GIP} or Tv_{TSS}, respectively) for the development. **Qp criterion:** The post-development hydrologic condition of any permanently protected soil restoration areas is equivalent to those of a similar cover type (e.g., meadow, brush, woods) in FAIR condition.

Table 4-11 continued

<table>
<tr><th>GIP Incentive</th><th>Eligibility Criteria</th><th>Application Criteria</th></tr>
<tr>
<td>Use of the Stream Buffer Preservation GIP</td>
<td>
A stream buffer is a <u>permanent</u>, mature forest or reforested, natural conservation area along a stream that physically separates the stream from development. Buffers provide storm and stream water quality benefits such as protection, infiltration, evapotranspiration, filtration, shade, and habitat.
Eligibility requires <u>a minimum average stream buffer width of 50 feet across one side of the stream</u> and <u>permanent preservation and protection</u> of a <u>mature forest or reforested</u> stream buffer. Pervious trails, walkways, and other passive recreation areas may be present. There are no impervious areas, except those associated with utilities or roadway/pedestrian crossings. The GIP shall be designed and installed in accordance with this manual.
A mature forest buffer is defined as an undisturbed stream buffer where at least 90% of its area is covered during the summer months with the foliage of mature forest trees. The ground surface is comprised of forest litter and naturally occurring understory vegetation and is undisturbed by another land use.
A reforested buffer area is defined as an undisturbed stream buffer that requires reforestation (i.e., the planting of immature trees) to adequately establish a forested buffer.
See also Chapter 5, Section 5.4.5.
</td>
<td>
Rv criterion and TSS Removal criterion: Subtract a percentage of any permanently protected stream buffer area from the total site area when calculating the GIP or TSS treatment volume (Tv_{GIP} or Tv_{TSS}, respectively) for the development. The percentage is determined using the table below.
<table>
<tr><th rowspan="2">Average Buffer Width</th><th colspan="2">% Reduction of Stream Buffer Area used to determine Tv</th></tr>
<tr><th>Mature Forest</th><th>Reforested</th></tr>
<tr><td>0 to 49 feet</td><td>No incentive</td><td>No incentive</td></tr>
<tr><td>50 to 100 feet</td><td>50 to 100%</td><td>Divide average width by 2</td></tr>
<tr><td>> 100 feet</td><td>100%</td><td>50%</td></tr>
</table>
Example 1: A mature forest buffer having an average width of 36 feet is preserved. No reduction in Tv is allowed.
Example 2: A mature forest buffer having an average width of 64 feet is preserved. A 64% reduction in Tv is allowed.
Example 3: A reforested buffer having an average width of 64 feet is preserved. Tv reduction = 64/2 = 32%.
Qp criterion: The post-development hydrologic condition of any permanently protected buffers are as follows:
Reforested buffer: Woods-grass combo – <u>FAIR</u> condition*
Mature forest buffer: Woods – <u>GOOD</u> condition*
* See Table 2-2c in Urban Hydrology for Small Watersheds (USDA, 1986) for runoff curve numbers for other agricultural lands.
</td>
</tr>
</table>

Table 4-11 continued

GIP Incentive	Eligibility Criteria	Application Criteria
Use of Green Roof or Permeable Pavement GIPs	Green roof and permeable pavement GIPs reduce of amount of storm water generated on a development through evapotranspiration or infiltration. A green roof GIPs may also be used to capture water for a cistern. Eligibility requires the ***permanent protection*** of the GIP area. The GIP shall be designed and installed in accordance with this manual.	**Rv or TSS Removal criterion:** Subtract 50% of any areas covered by a green roof or permeable pavement from the total site area when calculating the GIP or TSS treatment volume (Tv) for the development. Green roofs and permeable/porous paver systems do not provide flood protection, so an incentive is not provided for the calculation of Qp.

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4.2.8 80% TSS Pollutant Removal

4.2.8.1 Background

The methodology provided in this section must be applied to satisfy Birmingham storm water quality requirements when:

- GIPs are used, but they alone cannot achieve the Rv Standard of 0.22 or less; or
- GIPs are not used at all.

In these situations, the site design must achieve 80% TSS Removal standard. Examples of BMPs that will be employed to meet this standard include extended detention ponds, sand filters, and wet ponds.

When attempting to comply with the 80% TSS Removal standard, it is important to keep in mind that the following three requirements must be met.

1. 80% TSS Removal must be achieved for the remainder of the treatment volume if GIPs have been used or for the full treatment volume if GIPs have not been used.
2. All impervious surfaces must be managed by a GIP or TSS Removal BMPs (see Section 4.2.1, item #2 regarding fringe areas of a site). Note that for a new development this includes all impervious surfaces, while for a redevelopment this includes only impervious surfaces that have been added as part of the redevelopment.
3. There must be sufficient storage volume in the proposed GIP(s) and/or TSS Removal BMPs to capture the treatment volume from the required 1.1 inch of rain (set forth by the NPDES-MS4 permit).

If these conditions cannot be met, the TSS Standard has not been achieved. Ideally, TSS Removal BMPs will only be applied when the site design cannot support full achievement of the Rv Standard due to limitations in the application of GIPs (see limitations in Chapter 3). TSS Removal BMPs are applied only to the volume of the 1.1-inch rainfall that is not managed using the Rv Method. Therefore, all site designs will start with application of the Rv Method to calculate a weighted Rv for the site, even if LID and GIPs are not used. However, there are design benefits that result from the use of LID and GIPs, regardless of whether Rv Standard is attained.

These benefits include:

- ❖ The curve number used for peak flow calculations can be adjusted to recognize the storm water captured by GIPs.
- ❖ The volume of storm water that must be managed by TSS Removal BMPs will be reduced based on the Rv achieved using LID and GIPs.

This section provides the policies, tables and equations that will be used to calculate compliance with the TSS Standard. Design specifications for TSS Removal BMPs are provided in Chapter 6 of this manual.

4.2.8.2 Accepted TSS Removal BMPs

Table 4-12 provides Birmingham's-accepted TSS Removal BMPs and the TSS removal percentage used to calculate compliance with the TSS Standard. The values reflect expected average annual TSS loads in typical urban post-development storm water when the structural BMP is sized, designed, constructed and maintained in accordance with Chapter 6 specifications.

Table 4-12. BMP Removal Rates for Total Suspended Solids

TSS Removal BMP	TSS Removal Value (%)
Dry Detention Pond	60%
Dry Extended Detention Pond	60%
Water Quality Swale/Enhanced Swale	80%
Gravity (oil-grit) Separator	40%

TSS Removal BMP	TSS Removal Value (%)
Manufactured Treatment Device	See Chapter 6
Open Channel[1]	50%
Sand Filters (Surface & Perimeter)	80%
Storm Water Wetland/Submerged Gravel Wetland	80%
Storm Water Wet Ponds	80%
Underground Detention	See Chapter 6

1 Refers to open channel practice designed for hydraulic control.

4.2.8.3 Calculating TSS % Removal for BMPs in Parallel

The percent TSS removal (% TSS) that is achieved on a site can be calculated using **Equation 4-10**, which is an area-weighted TSS reduction equation that accounts for the TSS reduction contributed from BMPs that are treating separate areas and not being used in series.

$$\boldsymbol{weighted\ TSS\%} = \frac{\sum_1^n (TSS_1 A_1 + TSS_2 A_2 + \ldots + TSS_n A_n)}{\sum_1^n (A_1 + A_2 + \cdots + A_n)} \qquad \textbf{Eq. 4-10}$$

Where:

weighted TSS% = weighted TSS Removal % for the area treated by the TSS Removal BMPs

TSS_n = TSS Removal % for an individual BMP from Table 4-12

A_n = the area draining to an individual BMP (acres)

4.2.8.4 BMPs in Series and Flow-Through Situations

BMPs in Series: The case of two or more TSS Removal BMPs in series, where storm water is treated in one BMP and discharged into another BMP for further treatment, is called a treatment train. **Equation 4-11** is used to calculate the total % TSS removal for a treatment train comprised of two or more TSS Removal BMPs.

$$TSS_{train} = TSS_{up} + TSS_{down} - \frac{(TSS_{up}\ x\ TSS_{down})}{100} \qquad \textbf{Eq. 4-11}$$

Where:

TSS_{train} = TSS Removal % for treatment train (%)

TSS_{up} = TSS Removal % - upstream BMP (Table 4-12)

TSS_{down} = TSS Removal % - downstream BMP (Table 4-12)

Flow-Through Condition: TSS Removal BMPs within a treatment train may sometimes be separated by a CDA. For purposes of this manual, this is called a "flow-through" condition. In this case, **Equation 4-12** is used since some of the flow entering the downstream BMP has not been treated by the upstream BMP.

$$TSS_{train} = \frac{TSS_{up}CDA_{up} + TSS_{down}CDA_{down} + \frac{TSS_{down}CDA_{up}\,(100 - TSS_{up})}{100}}{CDA_{up} + CDA_{down}} \qquad \textbf{Eq. 4-12}$$

Where:

TSS_{train} = TSS Removal % for treatment train (%)

TSS_{up} = TSS Removal % - upstream BMP (Table 4-12)

TSS_{down} = TSS Removal % - downstream BMP (Table 4-12)

CDA_{up} = Contributing drainage area - upstream BMP (acres)

CDA_{down} = Contributing drainage area - downstream BMP (acres)

Several situations for TSS Removal BMPs in series and flow through conditions are possible. Calculation policies for each situation are listed below.

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

B. For development sites that have other TSS Removal BMPs for storm water treatment that are not included in the treatment train, TSS_{train} must be included in Equation 4-10 in the calculation of the overall % TSS removal for the site.

C. Equation 4-12 is not used when the TSS Removal BMP is placed in series with an upstream GIP. The TSS Standard is applied only to the volume that is not managed using GIPs. Therefore, the storage volume of the GIP is not a part of this remaining volume and the GIP is not included in the calculation of % TSS removal.

EXAMPLE 4-6: %TSS REMOVAL (FLOW-THRU CONDITION)

A storm water management system located on a 9-acre development site consists of a dry extended detention pond and a bioretention cell. Five (5) acres drain to an open channel that then drains to an underground pipe system. The pipe system receives discharge from an additional 4 acres that have not been treated for water quality. The pipe system discharges to a dry extended detention (ED) pond which is used for final treatment. Determine the % TSS removal for the site.

The % TSS removal value for each BMP located on the site is determined from Table 4-12: For the channel, TSS_{up} = 50% and for the ED pond, TSS_{down} = 60%. Use Equation 4-12 to calculate TSS_{train}, which in this situation represents the %TSS Removal for the entire site.

$$TSS_{train} = \frac{50\%(5ac) + 60\%(4ac) + \frac{60\%(5ac)\,(100-30)}{100}}{5ac + 4ac}$$

$$TSS_{train} = 77.8\%$$

The % TSS removal for the site is 66.7%, which is below the Pollutant Removal Performance Standard of 80% TSS Removal. Converting the open channel to a wet water quality swale would allow the upstream BMP to have a higher TSS removal ability and help the site meet the standard.

4.2.8.5 Calculating the TSS Treatment Volume (Tv_{TSS})

There are two basic scenarios for the application of TSS Removal BMPs on a development site, depending on the extent to which the Rv Method is applied at the development and whether the site designer wishes to use a GIP in series with a TSS Removal BMP. The various circumstances that could occur when using TSS Removal BMPs and the calculations required to determine compliance with the TSS Standard are described in the following sections.

BMPs Alone or in Parallel

This situation can occur as a result of two design conditions: 1) the development is severely runoff reduction limited and the Rv Method cannot be applied at all; or 2) one or more GIPs are designed but will have completely different contributing drainage areas than the TSS Removal BMP(s). In this situation, the TSS Removal BMP is sized for the storm water volume that is not captured by GIPs. In the case of design condition 1 described above, the TSS Removal (BMPs) must treat the volume resulting from the entire 1.1 inch of rainfall. The volume that must be treated by the TSS Removal BMP (Tv_{TSS}) is determined using **Equation 4-13**.

$$Tv_{TSS} = Tv_{total} - Tv_{GIPs} \qquad \textbf{Eq. 4-13}$$

Tv_{TSS} = the volume of runoff that must be treated by TSS Removal BMPs to comply with the 80% TSS Removal Standard

Tv_{GIPs} = the total capture volume of all structural GIPs proposed for the development. Use Equation 4-4. If no GIPs are designed for the site, then $Tv_{GIPs} = 0$.

Tv_{total} = the capture volume from the 1.1-inch rainfall over the entire development (Use Equation 4-4 without a multiplier. In Equation 4-4, the weighted Rv and contributing drainage area must reflect the entire development area for new developments, or the entire applicable area for redevelopments.)

EXAMPLE 4-7: CALCULATING Tv_{TSS} (BMPs IN PARALLEL)

A site designer is sizing a micropool extended detention (ED) pond (a TSS Removal BMP) for a 10-acre runoff reduction limited development. Three (3) acres of parking lot development discharges to a Level 2 bioretention. In a separate drainage area, the remaining 7 acres of the development (4.5 acres impervious cover and 2.5 acres meadow/turf on B soil) will discharge to the micropool ED pond. Determine the treatment volume for the bioretention BMP and the micropool ED pond.

Tv_{GIP} is calculated using Equation 4-4 (see below). It is determined by the site designer that the bioretention area can be sufficiently sized to capture this volume, thus a downstream BMP is not needed.

$$Tv_{GIP} = (1.25)(1.1\text{ in})(0.95)(3\text{ac})\left(\frac{43560\text{ ft}^2}{1\text{ ac}}\right)\left(\frac{1\text{ ft}}{12\text{ in}}\right) = 14{,}225\text{ ft}^3$$

When the Level 2 bioretention RR Credit (78%) is applied to the 3-acre drainage area, the Rv is reduced to 0.21, which is less than the target of Rv ≤ 0.22. Thus, the storm water quality performance standard is met in the CDA for the bioretention area.

The micropool ED pond is sized using Equation 4-13. First, find Tv_{total} using Equation 4-4 without the multiplier, which initially requires calculation of the weighted Rv for entire development without consideration of GIPs (use Equation 4-1): Rv (parking lot) = 0.95; Rv (meadow/turf on B soil) = 0.20.)

$$\text{Weighted Rv (for development)} = \frac{(0.95 \times 7.5\text{ ac}) + (0.20 \times 2.5\text{ ac})}{(10\text{ ac})} = 0.76$$

$$Tv_{total} = \left[(1.1\text{ in})(0.76)(10\text{ac})\left(\frac{43560\text{ ft}^2}{1\text{ ac}}\right)\left(\frac{1\text{ ft}}{12\text{ in}}\right)\right] = 30{,}347\text{ ft}^3$$

Applying Equation 4-13:

$$Tv_{TSS} = Tv_{total} - Tv_{GIP}$$

$$\text{Tv}_{\text{TSS}} = 30{,}347\text{ ft}^3 - 14{,}225\text{ ft}^3 = 16{,}122\text{ ft}^3$$

Note that the % TSS Removal for the micropool ED pond = 80%, so a properly sized pond will be sufficient to meet the TSS Removal standard of 80% TSS Removal.

BMPs in Series with a GIP

When using a GIP and TSS Removal BMP in series, the equation(s) used to determine Tv_{TSS} will depend on the compliance situation with the Rv Standard.

In short, the site design has not met the Rv Standard because it does not meet one or both of the following conditions.

1. A weighted Rv ≤ 0.22 for the entire development
2. Sufficient storage volume in the proposed GIP(s) to capture the entire treatment volume from the required 1.1 inch of rain

Equations 4-14, 4-15, and **4-16** will be used to calculate the TSS Treatment Volume (Tv_{TSS}) when a TSS Removal BMP is used in combination with an upstream GIP.

$$\boldsymbol{Tv_{TSS} = A + B} \qquad \textbf{Eq. 4-14}$$

Where:

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

A = TSS treatment volume if GIPs do not provide sufficient storage for the entire treatment volume (Tv_{GIP}). If GIPs capture the entire 1.1-inch rainfall, then A = 0. See **Equation 4-15** to calculate A.

B = TSS treatment volume if the weighted Rv > 0.22 after application of the Rv Method. If weighted Rv ≤ 0.22, then B = 0. See **Equation 4-16** to calculate B.

The application of Equation 4-14 is explained in tabular form in **Table 4-13**, which lists the combinations and the form of the equation that is used for each combination.

Table 4-13. GIP-TSS BMP Series Combinations

GIP-TSS BMP Combination	Rv Standard Compliance Situation		Form of Eq. 4-14 Used to Calculate Tv_{TSS}
	Is $Rv \leq 0.22$?	Do GIPs capture the entire Tv_{GIP}?	
GIP-BMP Combination 1	No	Yes	$Tv_{TSS} = B$
GIP-BMP Combination 2	Yes	No	$Tv_{TSS} = A$
GIP-BMP Combination 3	No	No	$Tv_{TSS} = A + B$

Equations 4-15 and 4-16 are provided below.

$$A = \frac{Mult.\left(P\ x\ Rv\ x\ A\ x\ \frac{43560}{12}\right) - Tv_{actual}}{Mult.} \qquad \textbf{Eq. 4-15}$$

$$B = P\ x\ Rv(1 - RR\ Credit)\ x\ A\ x\ \frac{43560}{12} \qquad \textbf{Eq. 4-16}$$

Where:

- Mult. = multiplier for the GIP from Table 4-8
- P = rainfall depth, 1.1 inches
- Rv = 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.)
- A = contributing drainage area to the GIP (acres)
- Tv_{actual} = treatment volume that will be captured by the GIP
- RR Credit runoff reduction credit for the GIP, from Tables 4-4 or 4-6

The examples that follow show how these equations are applied.

EXAMPLE 4-8: CALCULATING Tv_{TSS} (COMBINATION 1)

A site designer is performing water quality calculations for a 3-acre commercial parking lot development. A Level 1 infiltration trench on C soil (RR Credit = 45%) manages the Tv_{GIP} for the 2.5-acre parking lot but does not lower the weighted Rv for the site sufficiently to achieve Rv ≤ 0.22. Other GIPs are not feasible so the designer plans for a micropool ED pond (i.e., wet ED pond) downstream of the infiltration trench to meet the TSS Standard. The area of the infiltration trench is 0.2 acres, and it has a Rv = 0.05 (Forest on C soil). Determine the treatment volume for the micropool ED pond.

The Rv for the contributing drainage area to the infiltration trench is determined using Equations 4-1 and 4-2.

$$\text{Weighted Rv} = \frac{(0.95 \times 2.5\ \text{ac}) + (0.05\ \times 0.2\ \text{ac})}{(2.7\ \text{ac})} = 0.88$$

The treatment volume of the micropool ED pond is calculated using Equation 4-14 (and Equation 4-16) where A = 0 because the parking lot has sufficient storage volume to manage Tv_{GIP}. So, Equation 4-14 becomes:

$$Tv_{TSS} = \text{P x Rv}(1 - \text{RR Credit})\ \text{x A x}\ \frac{43560}{12}$$

$$= 1.1\ (0.88)(1 - 0.45)(2.7ac)\frac{43560}{12} = 5{,}218\ \text{ft}^3$$

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

EXAMPLE 4-9: CALCULATING Tv_{TSS} (COMBINATION 2)

A site designer is performing water quality calculations for a 5-acre development. The site's weighted Rv is less than 0.22 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 1.1-inch rainfall. The land cover is as follows: 4 acres of impervious surface (Rv = 0.95) and 1 acre of meadow/turf on B soil (Rv = 0.20). The entire development discharges to the Level 2 bioretention BMP, which can capture no more than 8,500 ft^3 (determined using Equation 4-4). Overflow from the GIP discharges to a micropool ED pond. **Determine the treatment volume for the micropool ED pond.**

EXAMPLE 4-9: CONTINUED

The weighted Rv for the development (without RR credits) is determined using Equation 4-1.

$$\text{Weighted Rv} = \frac{(0.95 \times 4\text{ ac}) + (0.20 \times 1\text{ ac})}{(5\text{ ac})} = 0.80$$

The required treatment volume for the development is calculated using Equation 4-14 (and Equation 4-15) where B = 0 because Rv was less than 0.22. So, Equation 4-14 becomes:

$$Tv_{TSS} = \frac{\text{Mult.}\left(\text{P x Rv x A x } \frac{43560}{12}\right) - Tv_{actual}}{\text{Mult.}}$$

$$= \left[\frac{1.25\left((1.1)(0.80)(5ac)\left(\frac{43560}{12}\right)\right) - 8{,}500\text{ ft3}}{1.25}\right]$$

$$Tv_{TSS} = \frac{19{,}965\text{ft}^3 - 8{,}500\text{ft}^3}{1.25} = 9{,}172\text{ ft}^3$$

Note that the % TSS Removal for the micropool ED pond = 80%, so a properly sized pond will be sufficient to meet the TSS Removal standard of 80% TSS Removal.

4.2.9 Determining Land Cover Areas

The determination of the area of impervious surfaces and/or other types of land cover is critical to storm water quality protection calculations. The policies, guidance, and equations for the measurement of land cover areas are provided in this section.

1. **Land cover area determination for single lot developments.** For planned unit developments and other single lot developments where the pervious land cover designations and impervious cover footprints are part of the proposed design plans, land cover areas shall be determined by measuring the areas of the proposed boundaries for all pervious land cover designations (Table 4-3) and impervious surfaces.

2. **Land cover area determination for residential subdivisions.** The coverage area of impervious surfaces is often not well-understood for proposed residential subdivisions at the time the development is submitted to the local jurisdiction for approval. The person(s) responsible for establishing the subdivision lot layout, streets, common area, and infrastructure often sells lots to subsequent property owners who establish the site layout on each individual lot. Therefore, the impervious area can usually only be measured for streets and common areas but must be estimated on individual lots. Pervious land cover areas and common-use impervious areas (roadways, common areas, etc.) can then be determined using measurements.

Equation 4-17 and **Table 4-14** are used for impervious area estimation on individual lots. **Example 4-10** illustrates land cover determination for residential subdivisions.

$$IA_{total} = 1.1(\%I_{lots}A_{lots}) + IA_{common} \qquad \textbf{Eq. 4-17}$$

Where:

IA_{total}	=	the impervious area of the entire site or the contributing drainage area (acres)
1.1	=	ten percent increase factor to account for future changes in residential impervious cover that happen because of property owner renovations
$\%I_{lots}$	=	percent (%) impervious value for only the residential lots, including streets but excluding common areas. This value is determined using Table 4-14.
A_{lots}	=	total area of the residential lots used to determine $\%I_{lots}$, including streets but excluding common areas (acres)
IA_{common}		the area of impervious cover in common areas, excluding streets, as measured from the subdivision's concept plan or site plan (acres)

Table 4-14. Residential % Impervious Area Values by Lot Size

Residential Lot Size[1]	% Impervious[2]
Less than $^{1}/_{4}$ acre	65
$^{1}/_{4}$ acre	38
$^{1}/_{3}$ acre	30
$^{1}/_{2}$ acre	25
$^{3}/_{4}$ acre	22.5[3]
1 acre	20
2 acres or greater	15

1 Where the average lot size falls between the categories shown, interpolate between the ranges to determine the % impervious value.

2 % impervious values include lots streets. Common areas must be measured separately.

3 The % impervious value is interpolated from SCS data.

EXAMPLE 4-10: RESIDENTIAL IMPERVIOUS AREA CALCS.

A development of upscale residential cottages is being designed. The subdivision has a total area of 10 acres and will include 22 residential lots, each having an area close to ¼ acre for a total of 5.5 acres of land located on residential home lots. Of the remaining 4.5 acres, 2 acres will be used as green space amenity area within the center of the property with a wood chip pedestrian path and several park benches. The area will meet the criteria for the urban forest land cover designation. The remaining 2.5 acres will be utilized for a neighborhood pool area comprised of the pool and surrounding deck, a pool house and bathrooms, a small parking area, and surrounding turf with some small landscaped areas. The development has two distinct CDAs. CDA A is 4 acres in size and is comprised solely of residential lots (including roadways). CDA B is 6 acres in size and includes the remainder of the lots (1.5 acres) and the common areas. **Determine the land cover areas within each CDA.**

EXAMPLE 4-10: CONTINUED

The impervious area of CDA A is easily estimated because the land use is homogeneous (all 1/4 acre lots). Using Table 4-14, the impervious area of CDA A is:

$$\mathrm{IA}_A = 1.1(0.38 \text{ X } 4\ ac.) = 1.67\ ac.$$

From Table 4-3, the pervious areas on residential lots will have a turf land cover.

$$\mathrm{Turf}_A = 4.0\ ac. - 1.67\ ac. = 2.33\ ac.$$

The impervious area and associated turf area of the residential lots in CDA B is estimated using the same approach.

$$IA_{lots\ B} = 1.1(0.38 \text{ x } 1.5\ ac.) = 0.63\ ac.$$

$$Turf_{lots\ B} = 1.5\ ac. - 0.63\ ac. = 0.87\ ac.$$

The remaining impervious cover and pervious land cover areas for the urban forest amenity and the pool area in CDA B can be measured directly from the site plan. By measurement it is determined that the pool area has 2.13 acres of impervious cover and 0.37 acres of turf and landscaping. Although some trees are present in the landscape, the area does not meet the criteria for urban forest land cover designation.

All land cover areas are shown in the table below.

Land Cover	CDA A (4 acres)	CDA B (6 acres)
Forest	0 ac.	0 ac.
Urban Forest	0 ac.	2.0 ac.
Turf	2.33 ac.	0.87 + 0.37 = 1.24 ac.
Impervious Cover	1.67 ac.	0.63 + 2.13 = 2.76 ac.

4.3 Hydrology – Rainfall

Large portions of the text that follows were adapted or taken from Volume 2 of the *Georgia Stormwater Management Manual* (ARC, 2016).

4.3.1 Introduction

Hydrology deals with estimating flow peaks, volumes, and time distributions of storm water runoff. The analysis of these parameters is fundamental to the design of storm water management facilities, such as storm drainage systems and structural storm water controls. In the hydrologic analysis of a development site, there are a number of variable factors that affect the nature of storm water runoff from the site. Some of the factors that need to be considered include:

- Rainfall amount and storm distribution
- Drainage area size, shape and orientation
- Ground cover and soil type
- Slopes of terrain and stream channel(s)
- Antecedent moisture condition
- Storage potential (floodplains, ponds, wetlands, reservoirs, channels, etc.)
- Watershed development potential
- Characteristics of the local drainage system

There are several empirical hydrologic methods that can be used to estimate runoff characteristics for a site or drainage subbasin; however, the methods presented herein have been selected to support hydrologic site analysis for the design methods and procedures in this Manual.

- ☑ Rational Method
- ☑ SCS Unit Hydrograph Method
- ☑ USGS Regression Equations (for estimating peak flow only)

Table 4-15 lists the hydrologic methods and the circumstances for their use in various analysis and design applications. **Table 4-16** summarizes constraints on the use of these methods.

Table 4-15. Empirical Hydrologic Methods and Uses

Method	Manual Section	Rational Method	NRCS Method	USGS Regression Equations
Storage Facilities	4.7		X	X
Outlet Structures	4.7		X	
Gutters & Inlets	4.9	X		
Storm Drain Pipes	4.8	X	X	
Culverts	4.10	X	X	
Small Ditches	4.11	X	X	
Open Channels	4.11		X	
Open Ditches	4.11		X	
Energy Dissipation	4.12		X	

Table 4-16. Summary of Hydrologic Method Constraints
(Source: Georgia Stormwater Management Manual, 2016)

Method	Size Limitations[1]	Comments
Rational Method	25 to 200 ac	Method can be used for estimating peak flows and the design of small site or subdivision storm sewer systems. Not to be used for storage design.
NRCS Method[2]	0 to 2000 ac*	Method can be used for estimating peak flows and hydrographs for all design applications.

1 Size limitation refers to the drainage basin for the storm water management facility (e.g., culvert, inlet).

2 There are many readily available programs (such as HEC-1) that utilize this methodology

* 2,000-acre upper size limit applies to single basin simplified peak flow only.

Note that any hydrologic analysis is only an approximation. The relationship between the amount of precipitation on a drainage basin and the amount of runoff from the basin is complex. Further, little data on factors influencing the rainfall-runoff relationship is available. As a result, one should not expect exact solutions.

4.3.2 Rainfall

Rainfall is expressed in terms of frequency (average recurrence interval) or in annual probability of occurrence. So, for example, the "ten-year storm" for any given duration occurs on average once in ten years or has a probability of 10% in any year.

The intensity-duration-frequency (IDF) curves provided in **Figure 4-6** illustrate the average rainfall intensities in Birmingham corresponding to a particular storm for various storm durations. This data is kept, and updated on occasion, by the National Oceanic and Atmospheric Administration (NOAA) and is located at the website listed below. Select station BIRMINGHAM WSFO (0.-0829). **https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=al**

Tables 4-17 and **4-18** contain frequency and duration of events based on rainfall intensity and rainfall depth, respectively.

To avoid looking up intensities for smaller site designs with shorter storm durations, the IDF curves shown in Figure 4-6 have been fit with equations of the form:

$$\boldsymbol{i} = \frac{\boldsymbol{a}}{(\boldsymbol{t}+\boldsymbol{b})^{\boldsymbol{n}}} \quad \textbf{IDF curve fit equation}$$

Where:

i = Rainfall intensity (in/hr)

a, b, n = Factors for each return period rainfall (Table 4-19)

t = Storm duration (minutes)

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Figure 4-6. Birmingham Rainfall Intensity-Duration-Frequency (IDF) Curves *(Source: NOAA Atlas 14, Volume 9, Version 2, 2013)*

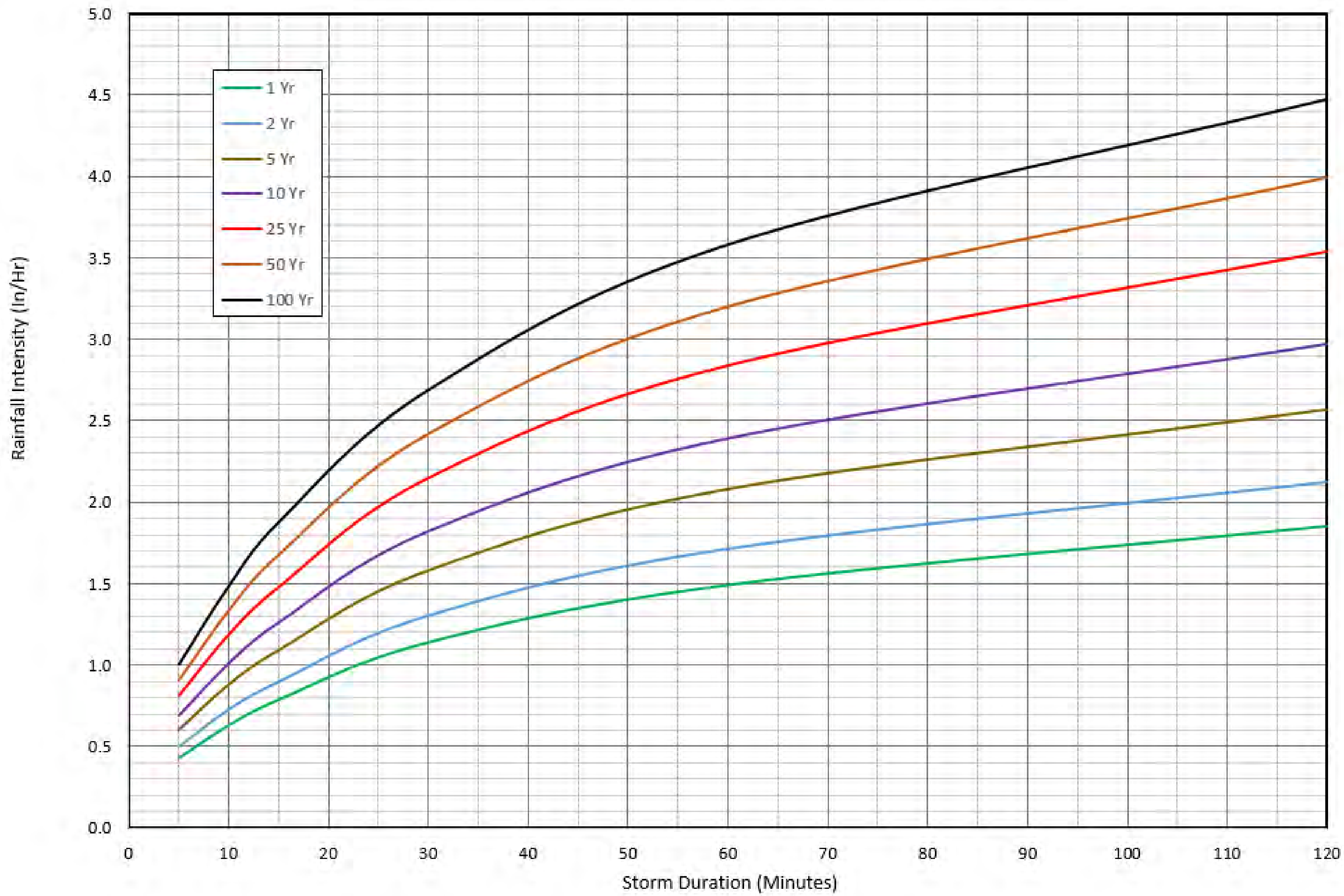


Table 4-17. Intensity-Duration-Frequencies for the City of Birmingham

Hours	Minutes	Return Frequency - Rainfall Intensity (in/hr)						
		1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr
0.08	5	5.20	5.95	7.2	8.27	9.77	11	12.2
0.17	10	3.80	4.36	5.27	6.05	7.15	8.02	8.91
0.25	15	3.09	3.54	4.28	4.92	5.82	6.52	7.24
0.5	30	2.27	2.60	3.16	3.63	4.30	4.83	5.38
1	60	1.49	1.71	2.08	2.39	2.84	3.20	3.58
2	120	0.925	1.06	1.29	1.48	1.77	2.00	2.23
3	180	0.69	0.788	0.957	1.11	1.32	1.50	1.68
6	360	0.421	0.476	0.575	0.666	0.802	0.917	1.04
12	720	0.254	0.285	0.343	0.398	0.483	0.558	0.639
24	1440	0.151	0.171	0.208	0.243	0.298	0.346	0.398

*Minimum time of concentration (T_C)

Table 4-18. Depth-Duration-Frequencies for the City of Birmingham

Hours	Minutes	Return Frequency - Rainfall Depth (in)						
		1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr
0.08	5	0.43	0.50	0.60	0.69	0.81	0.91	1.01
0.17	10	0.63	0.73	0.88	1.01	1.19	1.34	1.49
0.25	15	0.77	0.89	1.07	1.23	1.45	1.63	1.81
0.5	30	1.14	1.30	1.58	1.82	2.15	2.42	2.69
1	60	1.49	1.71	2.08	2.39	2.84	3.20	3.58
2	120	1.85	2.12	2.57	2.97	3.54	3.99	4.47
3	180	2.07	2.37	2.87	3.32	3.97	4.50	5.05
6	360	2.52	2.85	3.45	3.99	4.81	5.49	6.23
12	720	3.06	3.43	4.13	4.79	5.83	6.72	7.70
24	1440	3.63	4.10	4.99	5.83	7.15	8.30	9.56

*Minimum time of concentration (T_C)

Table 4-19 provides the appropriate factors used in the above IDF curve fit equation for each storm with return periods of interest accurate to within 2-3% up to the one-hour storm.

Table 4-19. Factors Used in the IDF Curve Fit Equation

Return Period	a	b	n
1	23.6698	5	0.6675
2	27.0612	5	0.6671
5	32.6224	5	0.6655
10	37.2816	5	0.6635
25	43.4669	5	0.6592
50	48.6523	5	0.6576
100	53.2821	5	0.6529

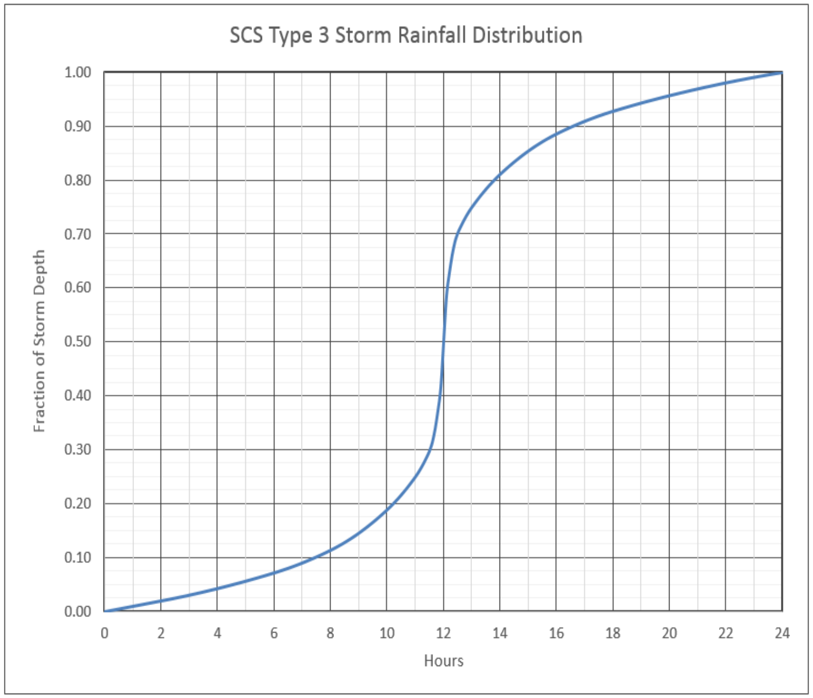
4.3.2.1 Rainfall Distributions

The hypothetical distribution of the design rainfall throughout a 24-hour period is provided for the Birmingham area in **Figure 4-7**. Most hydrologic models have the capability of using the most common SCS Type distributions. Most of the U.S. uses type II rains, but the Gulf Coast and Eastern Seaboard use type III rains. Type I and IA are used in some parts of the western states (Pitt, 2002).

The SCS Type III rainfall shall be used for hydrologic calculations in Birmingham, unless otherwise specified.

If tabular data is necessary for calculations it can be found at: https://www.wcc.nrcs.usda.gov/ftpref/wntsc/H%26H/rainDist/SCSrainfallDistTimeTransformations.xlsx

Figure 4-7. SCS Type III Rainfall Distribution



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4.4 Hydrology – Runoff

4.4.1 General Information

Proper calculation of runoff and the discharge hydrographs are critical to proper planning and sizing of storm drainage facilities. This section identifies the methodology to be used for determining the storm runoff design peaks and hydrograph generation for preparation of storm drainage studies, plans, and facility designs.

Peak discharge calculations represent the first level of runoff analysis. This analysis is used to determine the maximum flow rate at a given point resulting from a storm event. Peak discharge analysis is sufficient to design storm water conveyances and culverts whose purpose is only to convey runoff. The Rational Method and the National Resource Conservation Service (NRCS) Graphical Peak Discharge Methods are approved peak discharge calculation methods for use in Birmingham.

In contrast, a hydrograph represents runoff flow as it varies over time at a particular location. The area under the hydrograph represents the total volume of runoff. As opposed to peak rate of runoff, the hydrograph accounts for the variation in volume and flow rate over the duration of the of the storm event. Hydrographs are necessary to assess the effects of storm water detention/retention facilities. Hydrographs are also necessary for assessing the effects of combining runoff from two or more sub-catchments discharging to a common location in complex drainage areas with multiple sub-catchments.

Most standard hydrologic modeling software that uses the hydrograph generation and routing techniques included in this manual will be acceptable for use in Birmingham. These include, but are not limited to TR-55, TR-20, HEC-HMS, and various SWMM models. Engineers are responsible for understanding the limitations and correct application of modeling software used for hydrograph generation. In some cases, detailed hydrologic studies may have been completed for the area of interest and can be used with approval from the Director.

The hydrologic technique used must be appropriate for the design approach as indicated in this chapter or in the references of this chapter, such as *Urban Hydrology for Small Watersheds* (USDA, 1986).

4.4.2 The Rational Method

The Rational Method can be used to compute peak flows only for storm water conveyance drainage systems in watershed areas less than 200 acres. **It cannot be used for sizing detention ponds, regardless of watershed size.** The Rational Method assumes that all rainfall abstractions are represented by a single runoff coefficient, C. Where distinctive land use features are known, use of an area-weighted C factor is required.

The Rational Method equation is presented in **Equation 4-18**.

$$Q = C_f CIA \qquad \textbf{Eq. 4-18}$$

Where:

- Q = maximum rate of runoff (cfs)
- C_f = frequency factor (see Table 4-21)
- C = runoff coefficient representing the ratio of runoff to rainfall (see Table 4-20)
- I = average rainfall intensity for a duration equal to t_c (in/hr, Table 4-17)
- A = Contributing drainage area (acres)

Runoff coefficients are shown in **Table 4-20**. These coefficients are applicable for storms of 5-year to 10-year frequencies. Less frequent, higher intensity storms require modification of the coefficient because infiltration and other losses have a proportionally smaller effect on runoff (Wright-McLaughlin Engineers, 1969). The adjustment of the Rational Method for use with major storms can be using **Table 4-21**.

Table 4-20. Recommended Runoff Coefficient Values *(Source: Georgia Stormwater Management Manual, 2016)*

Description of Area	Runoff Coefficient (C)
Lawns	
Sandy soil, flat, 2%	0.10
Sandy soil, average, 2-7%	0.15
Sandy soil, steep, >7%	0.20
Clay soil, flat, 2%	0.17
Clay soil, average, 2-7%	0.22
Clay soil, steep, >7%	0.35
Unimproved areas (forest)	0.15
Business	
Downtown areas	0.95
Neighborhood areas	0.70
Residential	
Single-family areas	0.50
Multi-units, detached	0.60
Multi-units, attached	0.70
Suburban	0.40
Apartment dwelling areas	0.70
Industrial	
Light areas	0.70
Heavy areas	0.80
Parks, cemeteries	0.25
Playgrounds	0.35
Railroad yard areas	0.40
Streets	
Asphalt and concrete	0.95
Brick	0.85
Drives, walks, and roofs	0.95
Gravel areas	0.50
Graded or no plant cover	
Sandy soil, flay, 0-5%	0.30
Sandy soil, flat, 10-15%	0.40
Clay soil, flat, 0-5%	0.50
Clay soil, average, 5-10%	0.60

Table 4-21. Frequency Factors for the Rational Method Equation

Recurrence Interval (years)	C_f
10 or less	1.0
25	1.1
50	1.2
100	1.25

The Rational Method assumes:

- ❖ The rainfall intensity is uniform over the entire watershed during the entire storm duration.
- ❖ The storm duration is equal to t_c where t_c is the time required for runoff from the most remote part of the watershed to reach the point under design.

Some precautions should be considered when using the Rational Method.

! In determining the C factor for the drainage area, hydrologic analysis should consider any future changes in land use that might occur during the service life of the proposed storm water facility.

- ! Since the Rational Method uses a composite C and a single time of concentration value (t_c value for the entire drainage area), if the distribution of land uses within the drainage basin will affect the results of hydrologic analysis (e.g., if the impervious areas are segregated from the pervious areas), then the basin should be divided into sub-drainage basins.
- ! The charts, graphs, and tables included in this section are given to assist the design engineer in applying the Rational Method only. The design engineer should use sound engineering judgement when applying these aids and should make adjustments when specific site characteristics dictate that adjustments are necessary.

4.4.3 The NRCS (SCS) Curve Number Method

The NRCS Curve Number Method is a commonly used tool for estimating runoff from rainfall excess. The method was developed by the USDA NRCS (formerly SCS) and described in detail in Chapter 10 of the *National Engineering Handbook, Part 630 - Hydrology (NEH 630)* (USDA 2004). In this method, runoff is calculated based on precipitation, initial abstraction, and watershed storage. This method uses the runoff CN, where CN > 40. This number is a function of soil type and land use. (ALDOT, 2014)

The NRCS Curve Number Method can be used to compute peak flows for watersheds of any size. In Birmingham, the method shall be used to calculate peak discharges for the design of onsite drainage system components. The NRCS Curve Number Method for estimating storm water discharges is provided in *Urban Hydrology for Small Watersheds TR-55* (USDA, 1986). This resource can be found on the internet at: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf. The document provides detailed guidance, equations, tables, and calculation aids pertaining to:

- Estimating runoff using the NRCS Curve Number Method;
- Estimating the time of concentration (t_c) and travel time (T);
- Using the Graphical Peak Discharge Method; and,
- Using the Tabular Hydrograph Method.

4.4.4 Estimating Water Quality Peak Discharge

The peak rate of discharge for the water quality design storm (q_p), also called the water quality peak discharge, is sometimes needed to size storm water quality controls that are located off-line, such as sand filters and infiltration trenches. More traditional peak discharge calculation methods are not appropriate for this application for several reasons. First, the use of more traditional methods, such as the Rational Method, would require choosing an arbitrary design storm event that will differ from the rainfall event that must be treated for water quality. Further, conventional SCS methods have been found to underestimate the volume and rate of runoff for rainfall events less than two inches. This discrepancy in estimating runoff and discharge rates can lead to situations where a significant amount of runoff bypasses the storm water quality control due to inadequately sized diversion structures and leads to designing undersized bypass channels.

The method employed to calculate the water quality peak discharge is uses the runoff coefficient to find the depth of runoff for the water quality storm of 1.1 inches. The Graphical Peak Discharge Method is then used to find a unit peak discharge (q_u) that is combined with the runoff depth to find a peak runoff rate (q_p) (see **Equation 4-19** or USDA, 1986). This is adjusted by a pond and swamp factor (F_p).

$$q_p = q_u A_m Q F_P \qquad \textbf{Eq. 4-19}$$

Where:

q_p = peak discharge for storm water quality
q_u = unit peak discharge (csm/in)
A_m = drainage area (square miles)
Q = runoff (inches)
F_p = pond and swamp adjustment factor (see USDA, 1986)

However, the method can be greatly simplified when we assume that the sites draining to structural GIPs are small and highly impervious. In that case standard values can be used for $\mathbf{q_u}$, Q, F_p, and area (A) can be expressed in acres. Making these substitutions a simple equation for peak discharge for storm water quality design can be developed as shown in **Equation 4-20**.

$$q_p = 1.39 * A \qquad \text{Eq. 4-20}$$

Where:

q_p	=	peak discharge for storm water quality (cubic feet per second)
A	=	drainage areas (acres)

4.4.5 Regression Equations

To provide simple methods of estimating flood-peak discharges, the United States Geological Survey (USGS) has developed and published equations for rural areas in Alabama (USGS, 1998) and for urban areas in Alabama (USGS, 2007). Regression equations can be used for estimating peak discharges only. They must not be used for evaluating storage facilities and outlet structures. Regression equations for rural and urban areas are provided in **Table 4-22** and **Table 4-23**, respectively.

Table 4-22. USGS Regression Equations for Rural Areas in Alabama, USGS Region 1 *(Source: USGS, 1998)*

$Q_2 = 227A^{0.672}$
$Q_5 = 374A^{0.669}$
$Q_{10} = 482A^{0.669}$
$Q_{25} = 627A^{0.668}$
$Q_{50} = 739A^{0.667}$
$Q_{100} = 855A^{0.667}$

Table 4-23. Regional Flood Frequency Relations for Urban Streams in Alabama *(Source: USGS, 2007)*

$Q_2 = 95A^{0.648}PD^{0.407}$
$Q_5 = 226A^{0.670}PD^{0.298}$
$Q_{10} = 306A^{0.675}PD^{0.276}$
$Q_{25} = 417A^{0.670}PD^{0.253}$
$Q_{50} = 513A^{0.663}PD^{0.237}$
$Q_{100} = 618A^{0.656}PD^{0.223}$

4.4.6 Water Balance Calculations

Water balance calculations help determine if a drainage area is large enough, or has the right characteristics, to support a permanent pool of water during average or extreme conditions. When in doubt, a water balance calculation should be done for any BMP that maintains a permanent pool of storm water. Details of a rigorous water balance are beyond the scope of this manual. However, a simplified procedure is described herein that provides an estimate of pool viability and assess the need for more rigorous analysis. Water balance can also be used to help establish planting zones in a wetland design.

4.4.6.1 Basic Equations

Water balance is defined as the change in volume of the permanent pool resulting from the total inflow minus the total outflow (actual or potential. This is shown in **Equation 4-21**.

$$\Delta V = \sum I - \sum O \qquad \text{Eq. 4-21}$$

Where:

Δ	=	'change in'
V	=	permanent pool volume (acre-feet)
$\sum$	=	'sum of'
I	=	Inflows (acre-feet)
O	=	Outflows (acre-feet)

The inflows consist of rainfall, runoff, and baseflow into the pond. The outflows consist of infiltration, evaporation, evapotranspiration, and surface outflow out of the BMP. **Equation 4-22** reflects these factors.

$$\Delta V = P + Ro + Bf - I - E - Et - Of \qquad \text{Eq. 4-22}$$

Where:

Δ	=	'change in'
V	=	permanent pool volume (acre-feet)
P	=	precipitation (feet)
Ro	=	runoff (acre-feet)
Bf	=	baseflow (acre-feet)
I	=	infiltration (feet)
E	=	evaporation (feet)
Et	=	evapotranspiration (feet)
Of	=	overflow (acre-feet)

Rainfall (P): Rainfall values can be obtained from NOAA Atlas 14 at: http://hdsc.nws.noaa.gov/hdsc/pfds/.

Monthly values are commonly used for calculations of values over a season. Rainfall is then the direct amount that falls on the permanent pool surface for the time period being analyzed. When multiplied by the permanent pool surface area (in acres), it becomes acre-feet of volume.

Runoff (Ro): Runoff is equivalent to the rainfall for the period multiplied by the "efficiency" of the watershed, which is equal to the ratio of runoff to rainfall. In lieu of gage information, Q/P can be estimated one of several ways. The best method would be to perform long-term simulation modeling using rainfall records and a watershed model. However, should modeling not be possible, the following method can be used.

Equation 4-23 gives a ratio of runoff to rainfall volume for a particular storm.

$$R_v = 0.05 + 0.009(I) \qquad \text{Eq. 4-23}$$

Where:

R_V	=	runoff volume coefficient
I	=	percent of impervious cover

If it is assumed that the average storm that produces the runoff has a similar ratio, then the R_V value can serve as the ratio of rainfall to runoff. Not all storms produce runoff in an urban setting. Typical initial losses (often called "initial abstractions") are normally taken between 0.1 and 0.2 inches. In Georgia, this is equivalent to about a 10% runoff volume loss. (This will be assumed to be correct for Birmingham.) Thus, a factor of 0.9 should be applied to the calculated R_V value to account for storms that produce no runoff.

Equation 4-24 reflects this approach. Total runoff volume is then simply the produce of the runoff depth (Q) times the drainage area to the pond.

$$Q = 0.9PR_V \qquad \text{Eq. 4-24}$$

Where:

Q	=	runoff volume (inches)
P	=	precipitation (inches)
R_V	=	runoff volume coefficient

Baseflow (Bf): Most storm water ponds and wetlands have little, if any, baseflow, as they are rarely placed across perennial streams. If so placed, baseflow must be estimated from observation or through theoretical estimates. Methods of estimation and baseflow separation can be found in most hydrology textbooks.

Infiltration (I) – Infiltration is a very complex subject. The amount of infiltration depends on soils, water table depth, rock layers, surface disturbance, the presence or absence of a liner in the pond, and other factors. The infiltration rate is governed by Darcy's equation, presented in **Equation 4-25.**

$$I = AK_hG_h \qquad \textbf{Eq. 4-25}$$

Where:

I	=	Infiltration (acre-feet/day)
A	=	Cross-sectional area through which the water infiltrates (acres)
K_h	=	Saturated hydraulic conductivity or infiltration rate (inches per day)
G_h	=	Hydraulic gradient = pressure head/distance

G_h can be set equal to 1.0 for pond bottoms and 0.5 for pond sides steeper than 4:1. Infiltration rate can be established through infiltration tests, though not always accurately. As a first cut estimate, **Table 4-24** can be used.

Table 4-24. Saturated Hydraulic Conductivity *(Source: Ferguson and Debo, 1990)*

Material	Hydraulic Conductivity	
	inches/hour	feet/day
ASTM Crushed Stone, No. 3	50,000	100,000
ASTM Crushed Stone, No. 4	40,000	80,000
ASTM Crushed Stone, No. 5	25,000	50,000
ASTM Crushed Stone, No. 6	15,000	30,000
Sand	8.27	16.54
Loamy sand	2.41	4.82
Sandy loam	1.02	2.04
Loam	0.52	1.04
Silt loam	0.27	0.54
Sandy clay loam	0.17	0.34
Clay loam	0.09	0.18
Silty clay loam	0.06	0.12
Sandy clay	0.05	0.10
Silty clay	0.04	0.08
Clay	0.02	0.04

Evaporation (E): Evaporation is from an open water surface. Evaporation rates are dependent on differences in vapor pressure, which in turn depend on temperature, wind, atmospheric pressure, water purity, and shape and depth of the pond. It is estimated or measured in a number of ways, which can be found in most hydrology textbooks. Pan evaporation methods are also used. **Table 4-25** provides monthly pan evaporation rates for Birmingham, based on 20-year averages. Use a pan coefficient of 0.7 to convert the higher pan value to the lower lake values.

Table 4-25. Monthly Pan Evaporation Distribution in Birmingham *(Source: NOAA TR NWS 34, 1982*

Jan	Feb	Mar	Apr	May	Jun
1.79	2.40	4.06	5.86	7.23	7.14
Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
7.13	6.68	5.45	3.93	2.60	1.90

* Data provided in inches.

Evapotranspiration (Et): Evapotranspiration consists of the combination of evaporation and transpiration by plants. The estimation of Et for crops has become standard practice in many states. However, for wetlands, the estimating methods are not documented, nor are there consistent studies to assist the designer in estimating the demand wetland plants would put on water volumes. Literature values for places in the United States vary around the free water surface lake evaporation values when wetlands are being designed and emergent vegetation covers a significant portion of the pond surface. In these cases, conservative estimates of lake evaporation should be compared to crop-based Et estimates and a decision made. Crop-based Et estimates can be obtained from typical hydrology textbooks or from the Alabama Cooperative Extension Service at: ***www.aces.edu***.

Overflow (Of): Overflow is considered as excess runoff and in water balance design is either not considered, since the concern is for average values of precipitation, or is considered lost for all volumes above the maximum pond storage. Obviously, for long-term simulations of rainfall-runoff, large storms would plan an important part in pond design.

4.4.7 Off-site Analysis Policies

The design of storm water facilities shall consider and accommodate any discharges to them from areas upstream as stated in **Table 4-26**.

Table 4-26. Policies for On-Site & Off-Site Storm Flow Analysis

Analysis Type	Requirements for Use in Birmingham
Onsite Analysis	❖ The post-construction condition shall be used to determine runoff coefficients. ❖ Changes in flow patterns (from preconstruction conditions) caused by the proposed development shall be considered. ❖ The proposed grading shall be used to calculate the time of concentration and other runoff parameters.
Offsite Analysis	❖ Upstream drainage areas shall be considered developed for analysis of onsite storm water facilities. ❖ Where the offsite area is fully or partially undeveloped, the runoff shall be calculated assuming the basin is fully developed. Storm water parameters (i.e. C and CN) shall be based on current zoning. ❖ Downstream analysis of the impacts of drainage improvements shall be completed in accordance with the 10% rule defined in this manual.

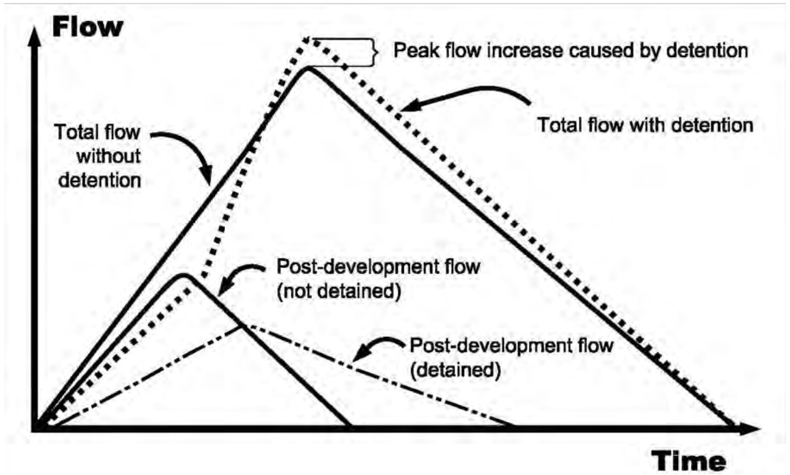
4.4.8 Downstream Analysis (The 10% Rule)

In general, the control of peak discharges at the outlet of a site, is determined such that the post-development peak discharge does not exceed the pre-development peak discharge. Typically, this control is achieved through construction of one or more on-site detention facilities. However, peak discharge control does not always provide effective water quantity control from the site and may actually exacerbate flooding problems downstream of the site. Moreover, master plans have shown that a development site's location within a watershed may preclude the requirement for overbank flood control from a particular site.

A major reason for negative impacts due to storm water detention facilities involves the timing of the peak discharge from the site in relation to the peak discharges in the receiving stream and/or its tributaries. If detention structures are indiscriminately placed in a watershed without consideration of the relative timing of downstream peak discharges, the structural control may actually increase the peak discharge downstream. An example of this situation is presented in **Figure 4-8**, which shows a comparison of the total downstream flow on a receiving stream (after development) with and without detention controls.

In Figure 4-8, the smaller dashed-dot and solid lines denote the runoff hydrograph for a development site with and without detention, respectively. These runoff hydrographs will combine with a larger runoff hydrograph of the receiving stream (not shown). The combined discharges from the site and receiving stream are shown in the larger solid and dashed lines.

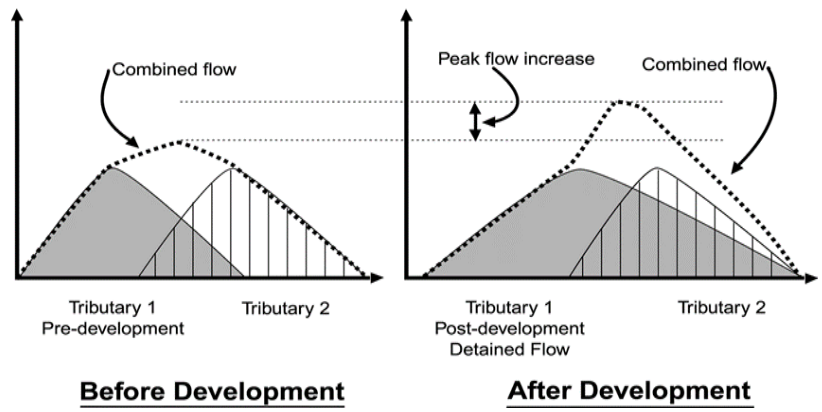
Figure 4-8. Potential Effect of On-Site Detention



Poor peak discharge timing can have an even greater impact when one considers all the developments located in a watershed and the cumulative effects of increases in runoff volume and the duration of high-volume runoff in the channel, as well as peak discharge timing. Even if peak discharges are handled effectively at the site level and immediately downstream, the longer duration of higher flows due to the increased volume from many developments located on or near a stream may combine with downstream tributaries and receiving streams to dramatically increase the downstream peak flows.

Figure 4-9 illustrates this concept. The figure shows the pre- and post-development hydrographs at the confluence of two tributaries. Development occurs, meets the local flood protection criteria (i.e., the post-development peak flow is equal to the pre-development peak flow at the outlet from the site), and discharges to Tributary 1. When the post-development detained flow from Tributary 1 combines with the first downstream tributary (Tributary 2), it causes a peak flow increase when compared to the pre-development combined flow. This is due to the increased volume and timing of runoff from Tributary 1, relative to the peak flow and timing in Tributary 2. In this case, the detention volumes on Tributary 1 would have to have been increased to account for the downstream timing of the combined hydrographs to mitigate the impact of the increased runoff volume.

Figure 4-9. Potential Effect of Cumulative Detention Basins



Potential problems such as those described above are quite common but can be avoided through the use of a storm water master plan and/or downstream analysis of the effects of a planned development. Studies have shown that if a developer is required to assess the impacts of a development downstream to the point where the developed property is 10% of the total drainage area, and there are no adverse impacts (i.e., stream peak discharge increases), then there is assurance that there will not be significant increases in flooding problems further downstream. For example, for a 10-acre site, the assessment would have to take place down to a point where the total accumulated drainage area is 100 acres. **Policies for the downstream analysis are provided in Chapter 3.**

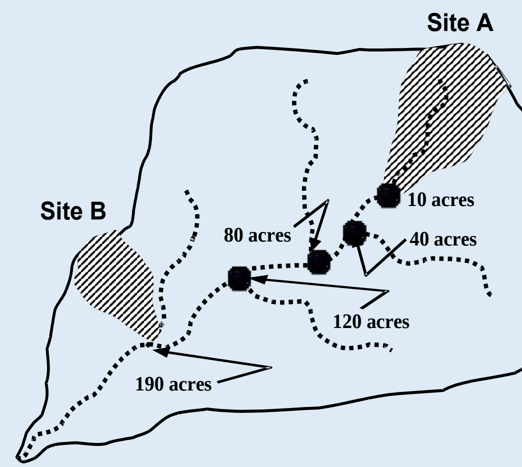
While this assessment does require additional labor on the part of the design engineer, it allows smart storm water management within a watershed. The assessment provides the developer, the City, and downstream property owners with a better understanding (and corresponding documentation) of the potential downstream impacts of development. In turn, the information identifies those developments for which waivers or reductions in the flood protection requirements may prove beneficial. Typical steps in the application of this analysis are as follows.

1. Using a topographic map determine the lower limit of the "zone of influence" (i.e., the 10% point), and determine all downstream analysis comparison points (at the outlet of the proposed land development, all downstream tributary junctions, and all public or major private bridges or culverts, ending at the next tributary junction *beyond* the 10% point).
2. Using accepted hydrologic methods/models defined previously in this chapter, determine the pre-construction peak discharges for the 2-year, 10-year, and 25-year, 24-hour storm events and the timing of those peaks at each comparison point.
3. Change the site land use to post-construction conditions and determine the post-construction peak discharges and timing for the same storms at the same comparison points. Compare results.
4. If post-construction conditions increase the peak flow at any of the comparison points, on-site flood protection BMPs must be redesigned (or conveyance improvements/flow easements may be allowed by the Director until all post-construction peak discharges from the site for all storm events do not exceed the pre-construction peak discharges at all comparison points.)

Example 4-11 provides a graphical description of the 10% Rule application.

EXAMPLE 4-11: TEN PERCENT RULE APPLICATION

The figure below illustrates the concept of the downstream analysis for two sites in a watershed. Site A is a development of 10 acres, all draining to a wet ED storm water pond. Looking downstream at each tributary in turn, it is determined that the analysis should end at the tributary marked "120 acres." The 100-acre (10%) point is between the 80-acre and 120-acre tributary junction points.



A HEC-1 (HEC-HMS) model of the 120-acre area is constructed using single existing condition sub-watersheds for each tributary. Key detention structures existing in other tributaries must be modeled. An approximate CN is used since the actual peak flow is not the key for initial analysis, only the increase or decrease is important. The accuracy in curve number determination is not as significant as an accurate estimate of the time of concentration. Since flooding is an issue downstream, the pond design is iterated several times until the peak flow does not increase at junction points downstream to the 120-acre point.

Site B is located downstream at the point where the total DA is 190 acres. The site itself is only 6 acres. The first tributary junction downstream from the 10% point is the junction of the site outlet with the stream. The total 190 acres is modeled as one basin with care taken to estimate the time of concentration for input into the model of the watershed. The model shows that a detention facility, in this case, will actually increase the peak flow in the stream.

4.5 Small Storm Extended Detention Design

4.5.1 Overview

The *City of Birmingham Post Construction Storm Water Ordinance* requires adherence to the Small Storm Extended Detention Standard for all new developments and many redevelopments (depending on impervious area). The standard requires extended detention of the small storm extended detention volume (EDv). The EDv is determined for the 1-year frequency, 24-hour storm over the entire site and must be discharged over no less than a 24-hour period. The ordinance provides for possible waivers of this standard for the following conditions:

- where the post-construction condition peak discharge at the outlet(s) of the development is less than 2.0 cfs at each offsite discharge location; or,
- for proposed developments that will discharge directly into open conveyances such as larger streams, rivers, wetlands, or lakes provided the discharge will not have an impact on stream bank or channel integrity.

4.5.2 Estimation of the Extended Detention Volume

NRCS methods in Chapter 10 of the *National Engineering Handbook, Part 630 - Hydrology (NEH 630;* USDA, 2004) can be used to develop peak discharge necessary for estimation of the extended detention volume (EDv) for the small storm ED standard prior to storage facility design. but must be modified to determine the volume for a 1-year frequency, 24-hour duration design storm event. The calculation procedure is as follows.

Step 1: The 1-year, 24-hour rainfall depth (P) for Birmingham is 3.63 inches.

Step 2: A runoff CN is then estimated using standard runoff CN estimation techniques (see *Urban Hydrology for Small Watersheds,* USDA, 1986).

Step 3: The CN is used to determine the initial abstraction (Ia) (see *Urban Hydrology for Small Watersheds,* USDA, 1986) and the ratio Ia/P is computed.

Step 4: The accumulated runoff (Q_d, inches) can then be calculated using the SCS method provided in the *National Engineering Handbook, Part 630 - Hydrology (NEH 630;* USDA 2004), where initial abstraction (Ia) = 0.2S.

Step 5: Compute the drainage area time of concentration (t_c) for the post-development land use using standard SCS methods (see *Urban Hydrology for Small Watersheds,* USDA, 1986).

Step 6: Use t_c with the ratio Ia/P to obtain the unit peak discharge, q_u, (see *Urban Hydrology for Small Watersheds,* USDA, 1986) **for the Type III rainfall distribution**. If the ratio Ia/P lies outside the range shown in the figure, either use the limiting values or use another peak discharge method.

Step 7: Knowing q_u and T (T = the extended detention time which is a minimum of 24 hours and maximum of 72 hours), the q_o/q_i ratio (peak outflow discharge/peak inflow discharge) can be estimated from **Figure 4-10**.

Step 8: V_s/V_r is then determined using the SCS detention basin routing formula of **Equation 4-26** or using the approximate detention basin routing for a Type II rainfall distribution from *Urban Hydrology for Small Watersheds* (USDA, 1986). Note that Equation 4-26 is suspect when the expression q_o/q^i approaches the limits of 0.1 and 0.8.

$$\frac{V_s}{V_r} = 0.682 - 1.43\left(\frac{q_o}{q_i}\right) + 1.64\left(\frac{q_o}{q_i}\right)^2 - 0.804\left(\frac{q_o}{q_i}\right)^3 \qquad \text{Eq. 4-26}$$

Where:

V_s = required storage volume (acre-feet)
V_r = runoff volume (acre-feet)
q_o = peak outflow discharge (cfs)
q_i = Peak inflow discharge (cfs)

Step 9: The required storage volume (EDv) can then be calculated using **Equation 4-27**. To check the EDv estimate, the volume must be incorporated into a BMP design, and the 1-year 24-hour storm routed through the BMP.

$$EDv = \frac{\left(\frac{V_s}{V_r}\right) Q_d A}{12} \qquad \textbf{Eq. 4-27}$$

Where:

Q_d = the runoff depth for the design storm (inches)
A = Total drainage area (acres)

Example 4-12 provides an example calculation for EDv.

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EXAMPLE 4-12: ESTIMATION OF EDv

Estimate the EDv necessary for a 50-acre wooded watershed, which will be developed as follows:

1) Forest land - good cover (hydrologic soil group B) = 10 ac
2) Forest land - good cover (hydrologic soil group C) = 10 ac
3) Residential with 1/3 acre lots (hydrologic soil group B) = 20 ac
4) Industrial development (hydrological soil group C) = 10 ac
5) Total impervious area = 18 acres
6) % of pond and swamp area = 0

Step 1. The 1-year, 24-hour design storm for Birmingham is 3.63 inches (Table 4-10).

Step 2. The CN is determined to be 72 using SCS Methods (see Section 4.4.3).

Step 3. Calculate Ia/P for CN= 72: Ia = 0.778, Ia/P = (0.778/3.63) = 0.21

Step 4. Q_d for 1-year, 24-hour storm is determined to be 1.21 inches, using Equations 4-7a and b.

Step 5. The time of concentration (Tc) is determined to be = 0.35 hrs using SCS Methods.

Step 6. The unit discharge is determined from Figure 4-10 using Tc and Ia/P from previous steps. q_u (1-year) = 135 csm/in

Step 7. EDv = V_S. Knowing q_u from Step 6 and T (extended detention time of 24 hours), find q_o/q_i from Figure 4-10, q_o/q_i = 0.120

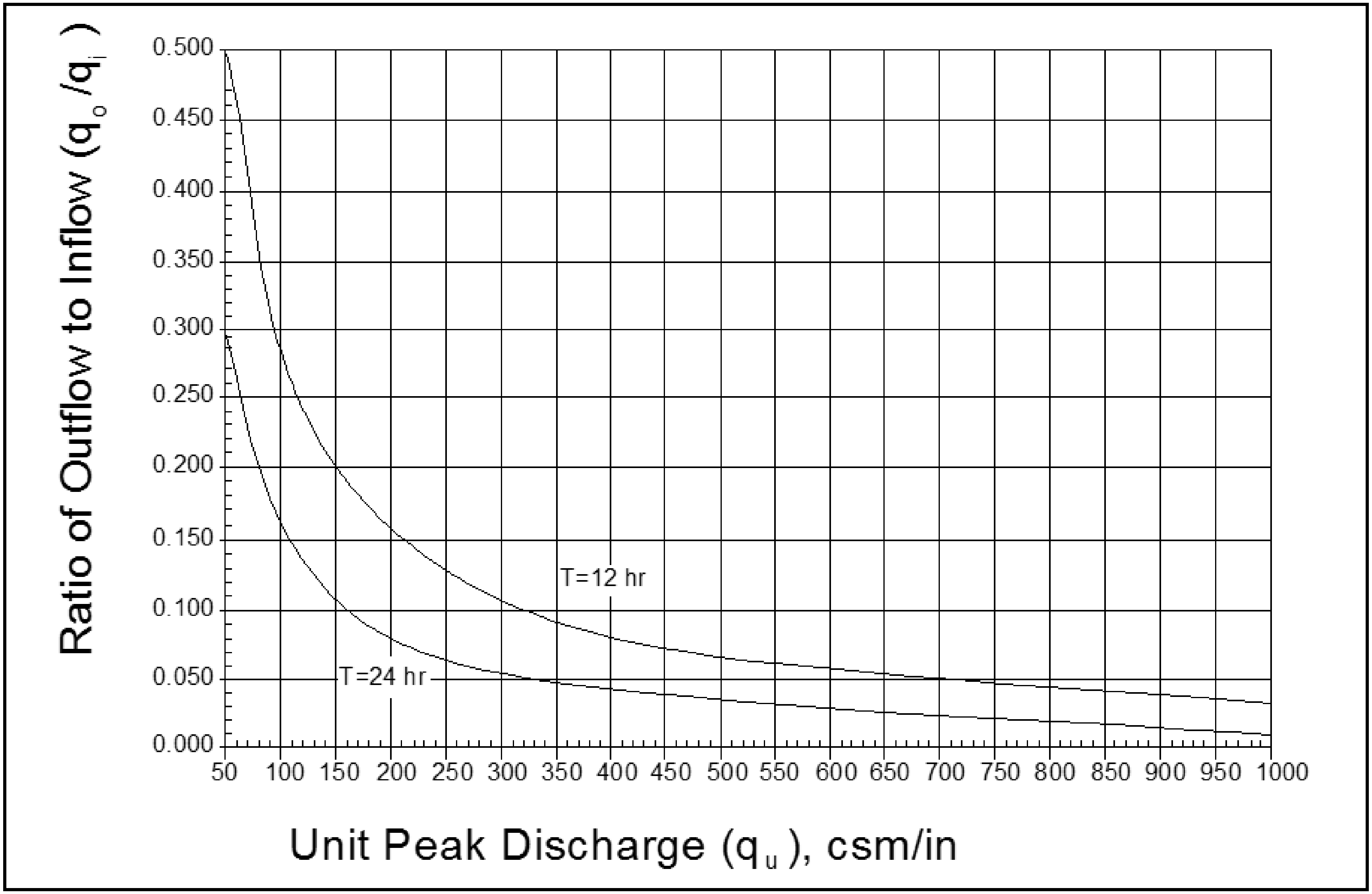
Step 8. Estimate storage/runoff using Equation 4-26:

$$\frac{V_s}{V_r} = 0.682 - 1.43\,(0.120) + 1.64\,(0.120)^2 - 0.804\,(0.120)^3$$
$$= 0.53$$

Step 9. The necessary detention volume is calculated using Equation 4-27:

$$V_s \approx \left(\frac{V_s}{V_r}\right) Q_d \frac{A}{12} = 0.53\,(1.21)\left(\frac{50}{12}\right) \approx 2.68\ acre\ feet$$

Figure 4-10. Detention Time vs. Discharge Ratios (Source: Maryland Department of the Environment, 1998)



4.6 GIP Underdrain Design

If an underdrain is used for an infiltration GIP, an underground storage layer of 12 to 18 inches shall be incorporated below the invert of the underdrain. The depth of the storage layer will depend on the target treatment and storage volumes needed to meet water quality criteria. However, the bottom of the storage layer shall be at least 2 feet above the seasonally high-water table and bedrock. The procedure to size underdrains is typically determined by the project engineer. In general, the following criteria shall be met:

- The minimum pipe diameter is 4 inches.
- Install 2 or more underdrains for each infiltration system in case one clogs. At a minimum, provide one underdrain for every 1,000 square feet of surface area.
- Include at least 2 observation /cleanouts for each underdrain, one at the upstream end and one at the downstream end. Cleanouts should be at least 4 -inch-diameter, vertical, non-perforated, Schedule 40 PVC pipe and should extend to the surface. Cap cleanouts with a watertight removable cap.
- Construct underdrains with Schedule 40 or SDR 35 Smooth Wall PVC pipe.
- Install underdrains with a minimum slope of 0.5%, particularly in HSG D soils (Note: To utilize Manning's equation, the slope must be greater than 0).
- Include a utility trace wire for all buried piping.
- For underdrains that daylight on grade, include a marking stake and animal guard.
- For each underdrain, have an accessible knife gate valve on its outlet to allow the option of operating the system as either an infiltration system, filtration system, or both. The valve should enable the ability to adjust the discharge flow, so the sum of the infiltration rate plus the under-drain discharge rate equals a 48-hour draw-down time.
- Perforations should be 3/8 inches. Use solid sections of non-perforated PVC piping and watertight joints wherever the underdrain system passes below berms, down steep slopes, makes a connection to a drainage structure, or daylights on grade.
- Spacing of collection laterals should be less than 25 feet.
- Underdrain pipes should have a minimum of 3 inches of washed #57 stone above and on each side of the pipe. Above the stone, 2 inches of choking stone is needed to protect the underdrain from blockage.
- Pipe socks may be needed for underdrains imbedded in sand. If pipe socks are used, then use circular knit fabric.

Various underdrain configurations and specifications are provided in Appendix F of the manual.

4.7 Storm Water Storage Practices

The policies established in this section shall be used in the design and evaluation of GIPs and BMPs used for purposes of storm water storage on land developments within Birmingham. Within this section, these are generally called "storage practices". Typically, these are detention or retention basins and engineered wetlands. Additional design requirements and specifications are provided for each type of GIP and BMP in Chapter 6 and in the Typical Details provided in Appendix F.

4.7.1 General

Hydrograph Routing. Storage practices shall be designed by calculating and routing a hydrograph through the practice using the hydrologic methods specified in this manual. No "shortcut" or storage estimation methods shall be used as a final design.

Fencing. Fencing may be required around detention ponds that will be owned by the City of Birmingham. All fencing shall include a top rail in accordance with Alabama Department of Transportation (ALDOT) construction standards and specifications. Hold Harmless Agreements may be executed by the owner for private systems.

Storage volume. Sediment discharged to storage practices during construction, whether intentionally or unintentionally, shall be removed after the pervious areas of the land development are permanently stabilized to reestablish the design storage volume of the practice. The design storage volume of such practices shall be confirmed after construction is complete on the record drawing. **Note: The use of the storage area for proposed infiltration-based GIPs as sediment traps during construction is prohibited. Such GIPs include bioretention areas, urban bioretention areas, infiltration trenches, and water quality channels.**

Large storage facilities. Certification of dam embankment design and stability, by an Alabama-registered Professional Engineer, shall be provided for storage practices that will be designed to detain volumes in excess of 100 acre-feet or earthen embankments higher than 25 feet.

Floodplain policies. The following conditions shall be provided in accordance with the City of Birmingham Floodplain Ordinance, adopted in October 1995.

a. Existing and future floodplains shall be preserved to the extent possible.
b. Storage facilities shall not be located within the 100-year floodplain.

4.7.2 Storage Practice Bottoms and Embankments

1. The bottom of the storage practice shall be sloped towards the outlet to prevent standing water. Other methods to achieve full discharge of storm water from the facility may be used, with written approval from the Director.

2. Control measures shall be installed within the storage practice to prevent transport of sediment and settled materials from detained storm water into the outlet structure and downstream receiving waters.

3. Slopes of earthen embankments shall be constructed with two to one (2:1) horizontal to vertical dimensions or flatter.

4. Storage practices used as sediment traps during construction must be returned to the post-construction design capacity.

5. Soil in all areas of the storage practice shall be permanently stabilized with a dense stand of grass or other appropriate vegetation or by other means (e.g., impervious surface) to eliminate bare soil exposure to rainfall, prevent erosion, and control sediment discharges. Any impervious surface used for this purpose must be shown in the SWMP and included in all hydrologic calculations.

6. Sheet flow over the side banks of storage practices is discouraged; off-site flow shall be routed to common locations and conveyed into the practices utilizing structural controls to minimize erosion.

4.7.3 Outlets and Outfalls

1. Storage practices, including the principal spillway or outlet structure, shall be designed in keeping with the design storm events identified by the flood protection performance standard.

2. In general, the outfall from a storage practice should be located to discharge to the nearest natural drainage feature or nearest storm water drainage system with adequate capacity to convey discharges from the storage facility.

3. Outlet structures for storage practices shall be designed to provide release of low flow volume to prevent standing water yet remain in keeping with performance standards for storm water quality protection and small storm extended detention.

4. An emergency overflow or spillways shall be provided for all detention and retention ponds, capable of passing the 100-year frequency, 24-hour duration storm event without catastrophic damage to the facility or downstream areas, unless the 100-year storm is accommodated through the principal spillway/outlet. Overflows or spillways may or may not be located near the

principal outlet structure for the practice, depending on the capacity of the downstream receiving water or storm water drainage system and the potential impact to downstream properties.

5. Trash racks and safety gates will be required for all outlet structures and pipes greater than or equal to 18 inches.

6. The outlet pipe for storage practices that will be dedicated to the City shall be constructed with O-ring reinforced-concrete pipe (RCP) for the entire length of pipes penetrating the embankment or dam; justifiable exceptions to this requirement may be accepted by the Director.

7. Energy dissipation structures shall be provided at storage practice outfalls to control discharged storm water to non-erosive velocities.

4.7.4 Extended Detention (ED) Outlet Design

Extended detention outlet sizing is required in design applications to meet the small stream ED standard or for extended detention BMPs (i.e., a wet ED pond, micropool ED pond, or shallow ED wetland). In both cases, an extended detention orifice or reverse slope pipe can be used for the outlet. For designs that combine both treatment and the small storm ED into one multi-purpose facility such as a wet or dry ED pond, two outlet orifices will be designed – one for water quality control (TSS removal) and one for the small storm ED standard.

(The following procedures are based on the water quality outlet design procedures included in the Virginia Stormwater Management Handbook, 1999.)

The outlet hydraulics for peak control design (overbank flood protection and extreme flood protection) is usually straightforward in that an outlet is selected that will limit the peak flow to some predetermined maximum. Since volume and the time required for water to exit the storage facility are not usually considered, the outlet design can easily be calculated, and routing procedures used to determine if quantity design criteria are met.

In an extended detention BMP for TSS removal or small storm ED, the storage volume is detained and released for a specified amount of time (24 to 72 hours). The release period is a brim drawdown, beginning at the time of peak storage of the treatment volume or EDv until the entire calculated volume drains out of the basin. This assumes that the brim volume is present in the basin prior to any discharge. In reality, water is flowing out of the basin prior to the full or brim volume being reached. Therefore, the extended detention outlet can be sized using either of the following methods. Both methods are outlined in **Examples 4-13 and 4-14** follow.

1. Approximate the orifice size using the average hydraulic head associated with the storage volume and the required drawdown time.

2. Use the maximum hydraulic head associated with the storage volume and maximum flow and calculate the orifice size needed to achieve the required drawdown time. Route the volume through the basin to verify the actual storage volume used and the drawdown time.

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EXAMPLE 4-13: AVERAGE HYDRAULIC HEAD METHOD

Using the data from the previous example, use the average hydraulic head method to calculation the size of the EDv orifice.

EDV = 0.76 ac ft = 33,106 ft^3

Max. Hydraulic Head (H_{max}) = 5.0 ft (from stage vs. storage data)

Step 1. Determine the average release rate to release the EDv over a 24-hour period.

$$Q = \frac{33106\ ft^3}{24\ hr\ (3600\ sec)} = 0.38\ cfs$$

Step 2. Determine the required orifice diameter by using the orifice equation and the average head on the orifice.

$$Q = CA(2hH)^{0.5}\ or\ A = \frac{Q}{C(2hH)^{0.5}}$$

$$A = \frac{0.38}{0.6[2(32.2)(5.0)]^{0.5}} = 0.05\ ft^3$$

Step 3. Determine the pipe diameter from:

$$A = \frac{3.14d^2}{4}\quad then\quad d = \left(\frac{4A}{3.14}\right)^{0.5}$$

$$D = \left[\frac{4(0.05)}{3.14}\right]^{0.5} = 0.252\ ft = 3.03\ in$$

So, use a 3-inch diameter EDv orifice.

The average hydraulic head method and average discharge method results in a 3.0-inch diameter orifice. The next example will show that the maximum hydraulic head method results in a 3.6-inch diameter orifice, though actual routing may result in a changed (i.e., reduced) orifice size.

EXAMPLE 4-14: MAXIMUM HYDRAULIC HEAD METHOD

A wet ED pond sized for the required EDv will be used here to illustrate the sizing procedure for a small storm ED orifice.

Given the following information, calculate the required orifice size for water quality design.

EDV = 0.76 ac ft = 33,106 ft^3

Max. Hydraulic Head (H_{max}) = 5.0 ft (from stage vs. storage data)

Step 1. Determine the maximum discharge resulting from the 24-hour extended detention requirement (release over a 24-hour period). It is calculated by dividing the EDv by the required time to find the average discharge, and then multiplying by 2 to obtain the maximum discharge.

$$Q_{max} = \frac{33106\ ft^3}{24\ hr\ (3600\ sec)} = 0.38\ cfs$$

$$Q_{max} = 2 * Q_{max} = 2 * 0.38 = 0.76\ cfs$$

Step 2. Determine the required orifice diameter by using the orifice equation and Q_{max} and H_{max}.

$$Q = CA(2hH)^{0.5}\ or\ A = \frac{Q}{C(2hH)^{0.5}}$$

$$A = \frac{0.76}{0.6[2(32.2)(5.0)]^{0.5}} = 0.071\ ft^3$$

Step 3. Determine the pipe diameter from:

$$A = \frac{3.14d^2}{4}\quad then\quad d = \left(\frac{4A}{3.14}\right)^{0.5}$$

$$D = \left[\frac{4(0.071)}{3.14}\right]^{0.5} = 0.30\ ft = 3.61\ in$$

So, use a 3.6-inch diameter EDv orifice.

Routing the EDv of 0.76 ac ft through the 3.6-inch EDv orifice will allow the designer to verify the drawdown time, as well as the maximum hydraulic head elevation. The routing effect will result in the actual drawdown time being less than the calculated 24-hours. The orifice size can then be reduced to achieve the required 24 hours.

4.8 Storm Water Conveyance Design

4.8.1 Purpose

This section establishes the minimum standards and technical design criteria for all storm water conveyances in Birmingham, regarding hydrology, size, and alignment. The primary function of storm water conveyances is to collect excess storm water from street gutters, convey the excess storm water through storm water conveyances and along the street right-of-way, and discharge it into a GIP or BMP, or the nearest receiving water body (FHWA 1996). The design of storm water conveyances presented in this section relies on fundamental hydrologic and hydraulic design concepts. Designers should refer to other sections in this chapter for additional design methodology for hydrologic, inlets, culverts, and open channels.

4.8.2 General Policies

Minimum design storm. In keeping with the drainage system design policies established in Chapter 3 of this manual, the minimum return period to be used in the design of storm water drainage conveyance systems is the 25-year return frequency storm event, unless otherwise specified by the Director. For designs that require a hydrograph to assess the effects of storage and timing, a 25-year return frequency, 24-hour duration storm event shall be used.

Required hydrologic methods. System components shall be designed by calculating peak discharges using the hydrologic methods specified in this manual.

Conveyance sizing. In each case, storm water conveyances shall be sized to carry the portion of the runoff that cannot be conveyed on the surface, as dictated by the available capacity in streets and swales during these design event. Designers shall ensure that storms in excess of pipe design flows can be safely conveyed through a land development without damaging structures or flooding major roadways.

Minimum diameter. The minimum diameter for a storm drainage pipe is 18 inches.

Pipe material. Storm sewer pipe shall be a minimum of Class 3 reinforced concrete if the storm sewer:

a. is to be transferred to the City of Birmingham for maintenance;
b. is located in a recorded easement; and/or
c. conveys offsite storm water runoff through a site.

Pipe materials other than reinforced concrete may be used on systems that do not meet the above criteria.

Inlet spacing. Inlets shall be spaced in street gutter lines to prevent flow from entering public road intersections and to allow one lane (based on lane width of the road) of traffic to remain open for local streets. Arterial and collector streets must have one travel lane in each direction open to traffic.

Hydraulic grade line (HGL). The HGL shall not exceed the crown of the pipe by more than five percent (5%) of the diameter of the pipe for the design storm.

Sizing for the 100-year design storm. The storm water conveyances shall be sized to convey the 100-year storm event for the post-construction condition if any of the following conditions are met:

a. The street capacity for the 100-year storm event is exceeded; especially where the grade slopes down behind the curb and the 100-year storm capacity is limited to the height of the curb.

b. The 100-year storm flows split off in an undesired direction (e.g., flow splits at intersections).

c. The storm water conveyance is accepting flow from an upstream storm water conveyance system or branch that is designed for the 100-year storm.

d. Regional storm water conveyances are designed for the 100-year storm.

e. The storm water conveyances must convey un-detained flows to a regional detention basin if an over-land flow path to the basin is not available.

4.8.3 Alignment and Placement Criteria

Straight alignment required. All storm water conveyances shall be constructed with a straight alignment between manholes. **Table 4-27** provides the minimum horizontal and vertical alignment criteria. Distances shall be measured from outside edge of pipe to outside edge of pipe.

Table 4-27. Horizontal and Vertical Alignment Criteria

Alignment of Conveyance Relative to:	Alignment		Comment
	Minimum Vertical Clearance	Minimum Horizontal Clearance	
Water Main	18 inches	10 feet	The distance shall be measured edge to edge. Approval from Birmingham Water Works will be required for lesser clearances.
Building Structure or Foundation	--	10 feet (@ depth < 10 feet) 15 feet (@ depth > 10 feet)	No comment.
Cover	3 feet	--	Minimum cover depends on the pipe size, type, and class, and the soil bedding condition. The storm sewer grade shall maintain a minimum cover to withstand AASHTO HS-20 loading on the pipe in vehicular traffic areas (existing or potential) and HS-15 loading in all other areas.

Minimum distance from water lines. In instances where it is not possible to maintain the minimum horizontal alignment specified in Table 4-27, the Director may allow deviation on a case-by-case basis. This deviation may allow installation of the storm water conveyance closer to the water main, provided that the water main is in a separate trench or on an undisturbed earth shelf located on one side of the sewer and at an elevation to where the bottom of the water main is at least 18 inches above the top of the storm water conveyance.

Minimum distance from additional utilities. The location of the utilities shall be derived from the best information available. Each utility company shall receive a set of plans prior to final submittal on which they may note changes or additions to utility information. The adequacy of the separation of the storm water conveyance and other utilities shall be determined by both the appropriate utility company and the design engineer. Any necessary relocation shall be closely coordinated with the respective utility company.

4.8.3.1 Placement in Existing Rights-of-Way and Easements

Conveyance location. Existing rights-of-way and easements shall be utilized for storm water conveyances if possible. Otherwise, consult with the City of Birmingham during the pre-concept conference (see Chapter 2) when determining locations for storm water conveyances. Service needs of both the present service area and future service areas should be considered when locating storm water conveyances.

Concrete pavement. In areas of concrete pavement, consideration shall be given to placing the storm water conveyance in a location such that when saw-cut, an edge of the pavement to be removed would coincide with an existing construction joint resulting in the need to only saw-cut one side of the pavement. Manhole structures shall be either completely outside the pavement or completely inside the pavement. The existence of curbs or proposals of future curb and gutter shall be considered when evaluating the benefit of reducing the number of manholes in curved streets.

4.9 Inlets

The purpose of this section is to establish a basis for the design of inlets to storm water conveyance systems. Storm water inlets are a vital component of the urban storm water collection and conveyance system. Inlets intercept excess storm water from streets and developed areas and transition surface flow into storm water conveyances. Proper inlet design includes both the proper inlet hydraulic capacity and appropriate inlet placement. If too few inlets are provided, if inlets are placed in the wrong location, or if inlets do not have adequate hydraulic capacity, then even amply sized pipes in the storm water conveyance system will not function as intended.

There are three general types of inlets acceptable for use in Birmingham, including curb opening (designated Type "HF Inlet"), valley (designated "Yard Inlet"), and combination inlets (designated Type "AF Inlet"). Typical installation settings include:

- Street curb and gutter
- Pavement depression
- Drainage swale or channel
- Greenspace or undeveloped area

Inlet components can be manufactured using cast-iron, steel, cast in place concrete, and/or pre-cast concrete. For inlets placed in the right-of-way, see also the City of Birmingham's *Standard Specifications for the Construction of Public Works Projects*.

4.9.1 Inlet Placement

Inlets must be placed at each location where surface runoff flow should be interrupted and transitioned into storm water conveyance system pipe flow. Inlets can be placed in roadside ditches, grass or lined swales, parking or pavement area depressions, and in roadway or parking area curbs and gutters. The following location requirements must be considered during the design of inlets.

a. Inlets shall be placed in all streets and roadway sags. For the 25-year design storm, the depth of ponded water at the inlet shall not exceed the values shown in **Table 4-28**. For the 100-year design storm, the depth of ponded water at the inlet shall not exceed the values shown in **Table 4-29**.

b. In developed areas, inlets shall be located in all pavement and green space depression areas where surface runoff collects and transitions to storm water conveyance pipe flow.

c. Inlets shall be placed in grass or lined swales and open channels where concentrated flow transitions to storm water conveyance pipe flow.

Table 4-28. Allowable Use of Streets for 25-Year Storm Runoff

Street Type	Maximum Street Encroachment	Street Width Face of Curb to Face of Curb (ft)	Maximum Top Width from Gutter T_{max} (ft)	Maximum Depth in Gutter Flow, d (ft)
Local	No curb overtopping. Flow may spread to crown of street.	28	15	0.30
		32	16	0.32
		36	18	0.36
Collector	No curb overtopping. Flow spread must leave at least one lane free of water with 5 ft on either side of street crown.	36	13	0.26
		40	15	0.30
		44	17	0.34
Arterial	No curb overtopping. Flow spread must leave at least two 10 ft lanes free of water with 10 ft on each side of street crown.	Coordinate allowable use with the agency having jurisdictional authority of the roadway.		

Table 4-29. Allowable Use of Streets for 100-Year Storm Runoff

Street Type	Maximum Depth and Inundated Area
Local and Collector	The Maximum Depth of Water: ❖ Shall not exceed 12 inches above the gutter flowline, and ❖ Shall not reduce the localized Flood Protection Grade to less than 12 inches. (Whichever is more restrictive)
Arterial	The Maximum Depth of Water: ❖ Shall not exceed 12 inches above the gutter flowline, ❖ Shall not reduce the localized Flood Protection grade to less than 12 inches, and ❖ Shall not exceed the street crown (to allow for emergency vehicles). (Whichever is most restrictive)

d. Inlet grate capacities shall be designed to adequately pass the storm water conveyance pipe design storm event flow with 50% of the inlet grate free open areas clogged.

e. An emergency overland flow path shall be included at street and roadway sags in the event that the inlet or storm water conveyance is not functioning. The depth of ponded water at the inlet shall not exceed 12 inches.

f. Depth of ponded water shall not exceed 8 inches in private development parking areas, except in areas used as detention.

g. Depth of ponded water shall not exceed 24 inches in green space areas, except in areas used as detention.

h. In streets and roadways, inlets shall be placed immediately upstream of intersections, pedestrian walkways, and handicap ramps. Required inlets shall be placed not closer than 2 feet from the upstream edge of walkways and handicap ramps.

i. In streets or roadways where opposing lanes are separated by a grass median or concrete center curb, inlets shall be placed upstream of a crossover.

j. On continuous roadway or street grades, inlet spacing is determined by limiting maximum width of gutter flow (Tmax). Inlets shall be spaced to collect a minimum of 75% of the watershed design flow. Bypass flow, flow not intercepted by an individual inlet, shall not exceed 25%. Bypass flow shall be considered when determining the location of the next downstream inlet. General inlet spacing on continuous grades is 300 feet to 600 feet provided the Tmax criteria is not exceeded. Exact spacing shall be computed by the designer. See Section 4.9.3 for more information on Tmax design.

k. Uniform inlet and casting types should be used on individual street and roadway projects. Uniformity limits confusion and misplacement of proper inlet types during construction.

4.9.2 Inlet Hydraulic Capacity

All storm water runoff that enters a sump or gutter must pass through an inlet to enter the storm water conveyance system. In most situations storm water is laden with debris and the inlet will be susceptible to clogging. Therefore, the capacity of inlets must account for this clogging potential. Design of inlet hydraulic capacity is separated into either a sump or continuous grade situation. The following sections include design considerations and figures for inlet capacity for these two situations: sump condition and continuous grade condition.

4.9.2.1 Sump Condition

Inlets in depressions or sumps function like weirs for shallow flow, but as the depth of storm water increases, inlets begin to function like an orifice. **Figures 4-11** through **4-14** provide the allowable inlet capacities in sump conditions. The use of combination or curb opening inlets are recommended for sag locations due to the potential for clogging.

Assumptions made for the figures are listed below.

- Weir flow assumed for water depths below 2 inches.

Weir **Equation 4.28**:

$$Q_1 = 3.30 * P * d^{1.5} \qquad \textbf{Eq. 4-28}$$

Where:

Q_1 = rate of flow into the inlet (cubic feet per second)
P = perimeter of grate (feet)
d = depth of water surface above inlet (feet)

- Orifice flow assumed for water depths above 4".

Orifice **Equation 4.29**:

$$Q_1 = 4.81 * A * d^{0.5} \qquad \textbf{Eq. 4-29}$$

Where:

Q_1 = rate of flow into the inlet (cubic feet per second)
A = net open area of grate (feet)
d = depth of water surface above inlet (feet)

- Transition flows assumed between 2" and 4" water depth.
- Clogging reduces weir length by 50%.
- Clogging reduces free open area by 50%.

4.9.2.2 Continuous Grade Condition

Inlet hydraulic capacity on a continuous grade is designed as a function of depth of water flow in the street gutter and the inlet grate constant. The grate constant is determined empirically by the inlet manufacturer.

Note that inlets shall be spaced so that allowable inlet capacity intercepts at least 75% of the gutter flow during the 25-year rainfall event.

Figures 4-15 through **4-17** provide the allowable inlet capacities in continuous grade conditions. Assumptions for the figures are listed below.

Inlet capacity on a continuous grade **Equation 4.30**:

$$Q_i = K * d^{5/3} \qquad \textbf{Eq. 4-30}$$

Where:

Q_i = rate of flow into the inlet (cubic feet per second)

K = Inlet grate constant based on grade geometry and longitudinal and transverse slopes (provided by manufacturer; Neenah inlet constants are utilized for comparable East Jordan grates)

d = maximum depth of water surface above inlet (feet)

- Casting capacity reduced by 50% for clogging.
- Continuous grade capacity curves only apply when street flow is at the maximum allowable depth. For lower gutter depths, the inlet interception rate will decrease.

Figure 4-11. Allowable Inlet Capacity for Green Space Areas – Depression Conditions *(Source: Fort Wayne, IN Design Standards Manual)*

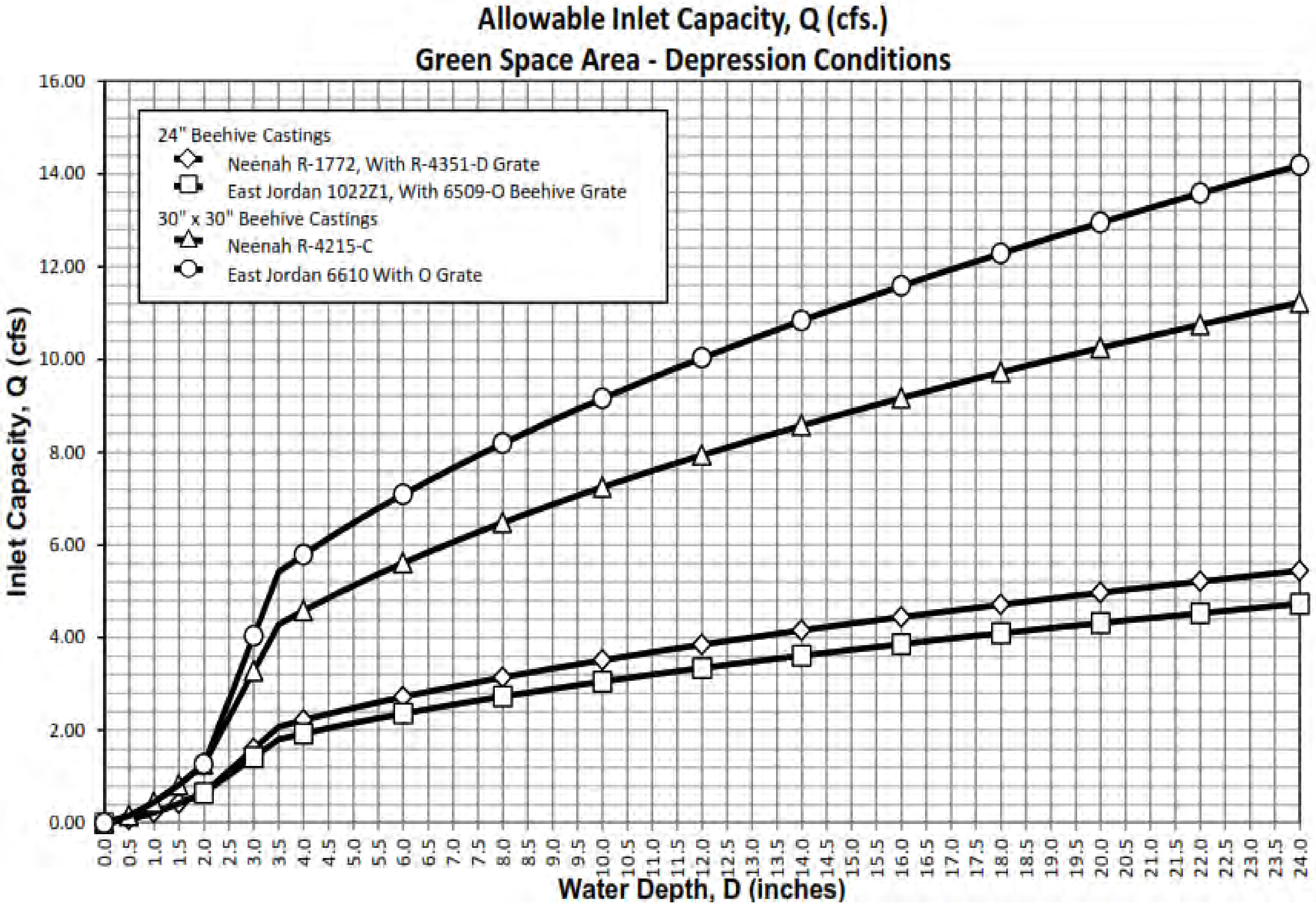


Figure 4-12. Allowable Inlet Capacity for Pavement Areas – Depression Conditions *(Source: Fort Wayne, IN Design Standards Manual)*

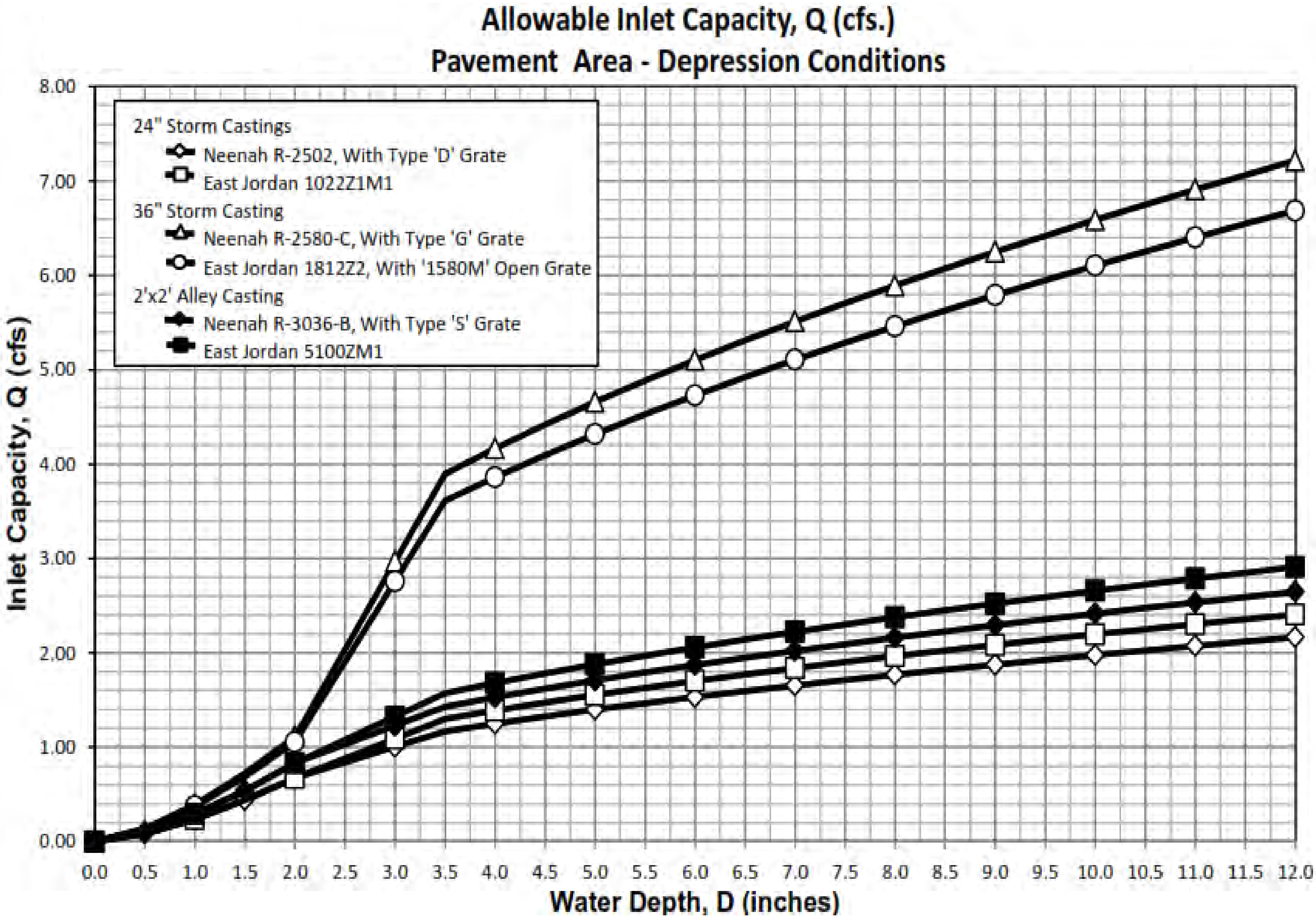


Figure 4-13. Allowable Inlet Capacity Sag Condition– Curb & Gutter for Neenah Foundry Castings *(Source: Fort Wayne, IN Design Standards Manual)*

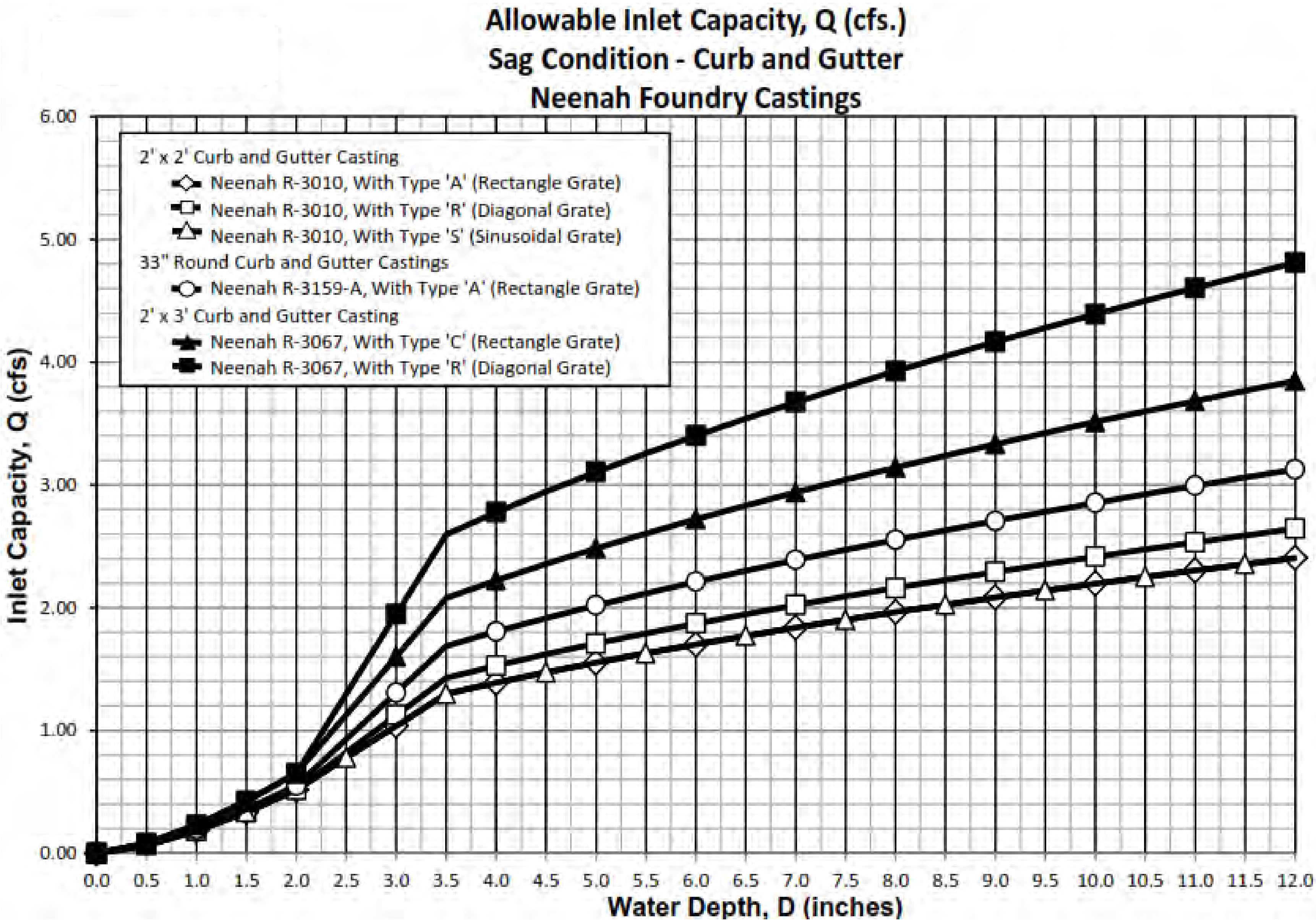


Figure 4-14. Allowable Inlet Capacity Sag Condition – Curb & Gutter for East Jordan Foundry Castings
(Source: Fort Wayne, IN Design Standards Manual)

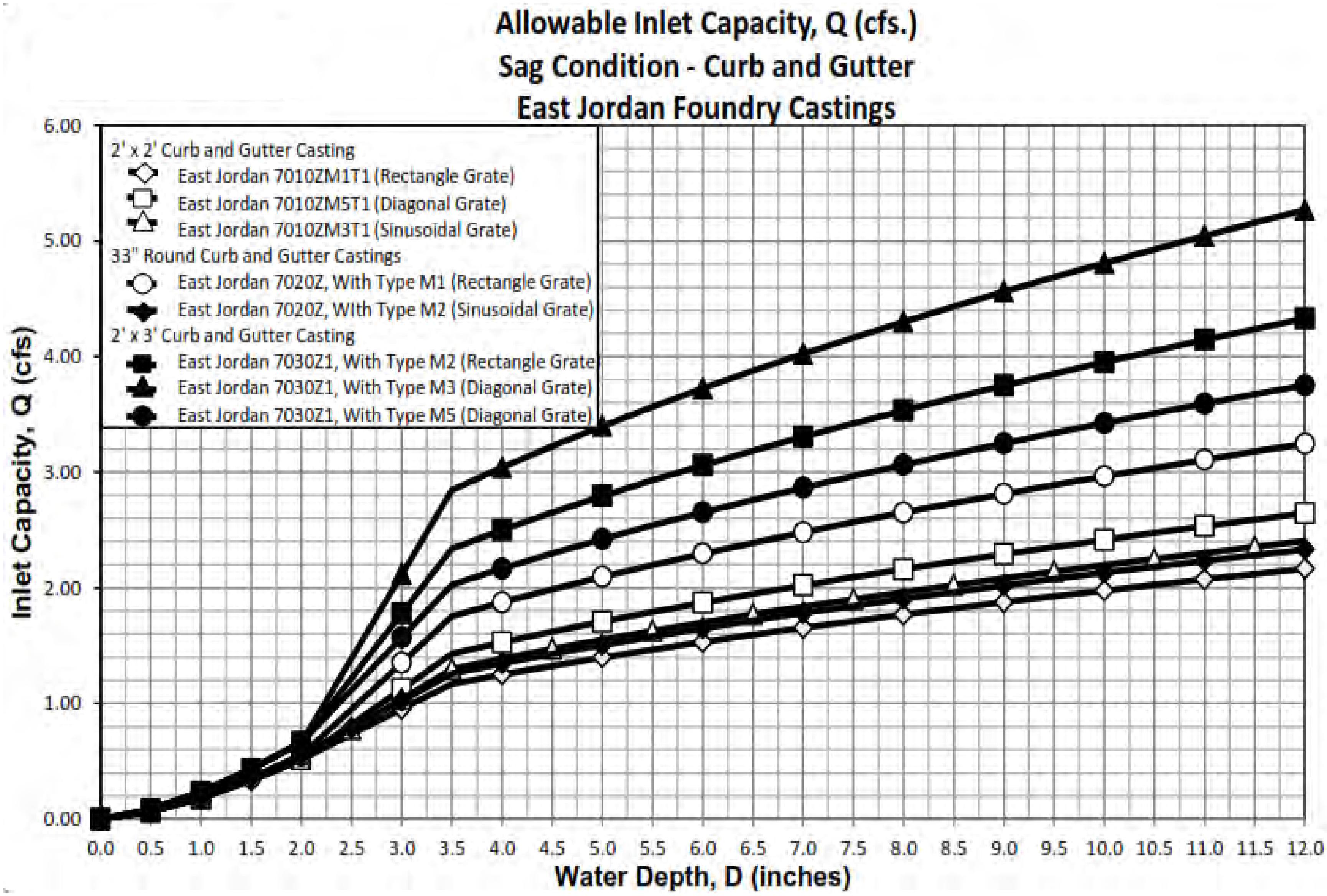


Figure 4-15. Allowable Inlet Capacity Continuous Grade Condition – 2' x 2' Curb & Gutter Combination Casting

(Source: Fort Wayne, IN Design Standards Manual)

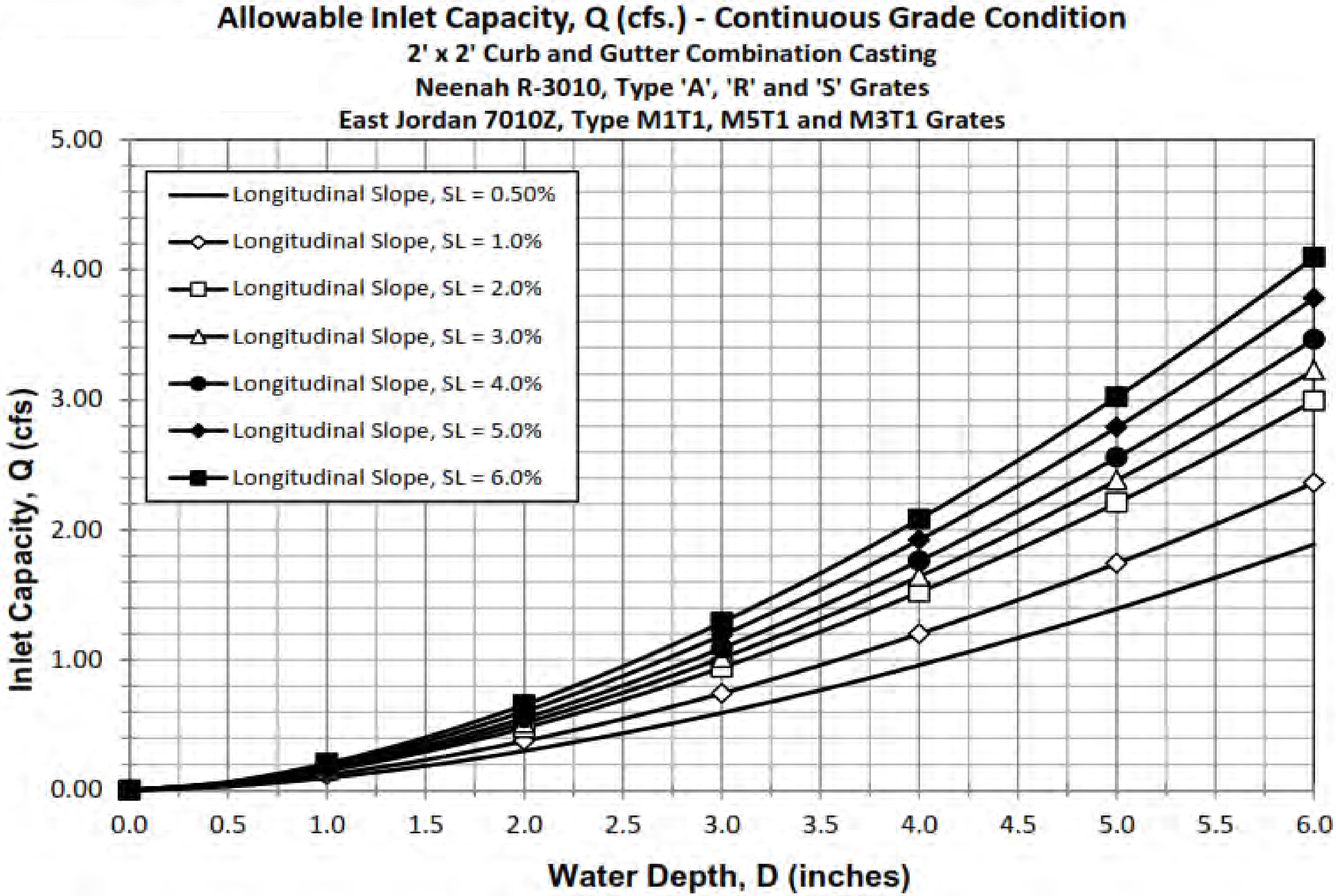


Figure 4-16. Allowable Inlet Capacity Continuous Grade Condition – 33" Round Curb & Gutter Combination Casting *(Source: Fort Wayne IN Design Standards Manual)*

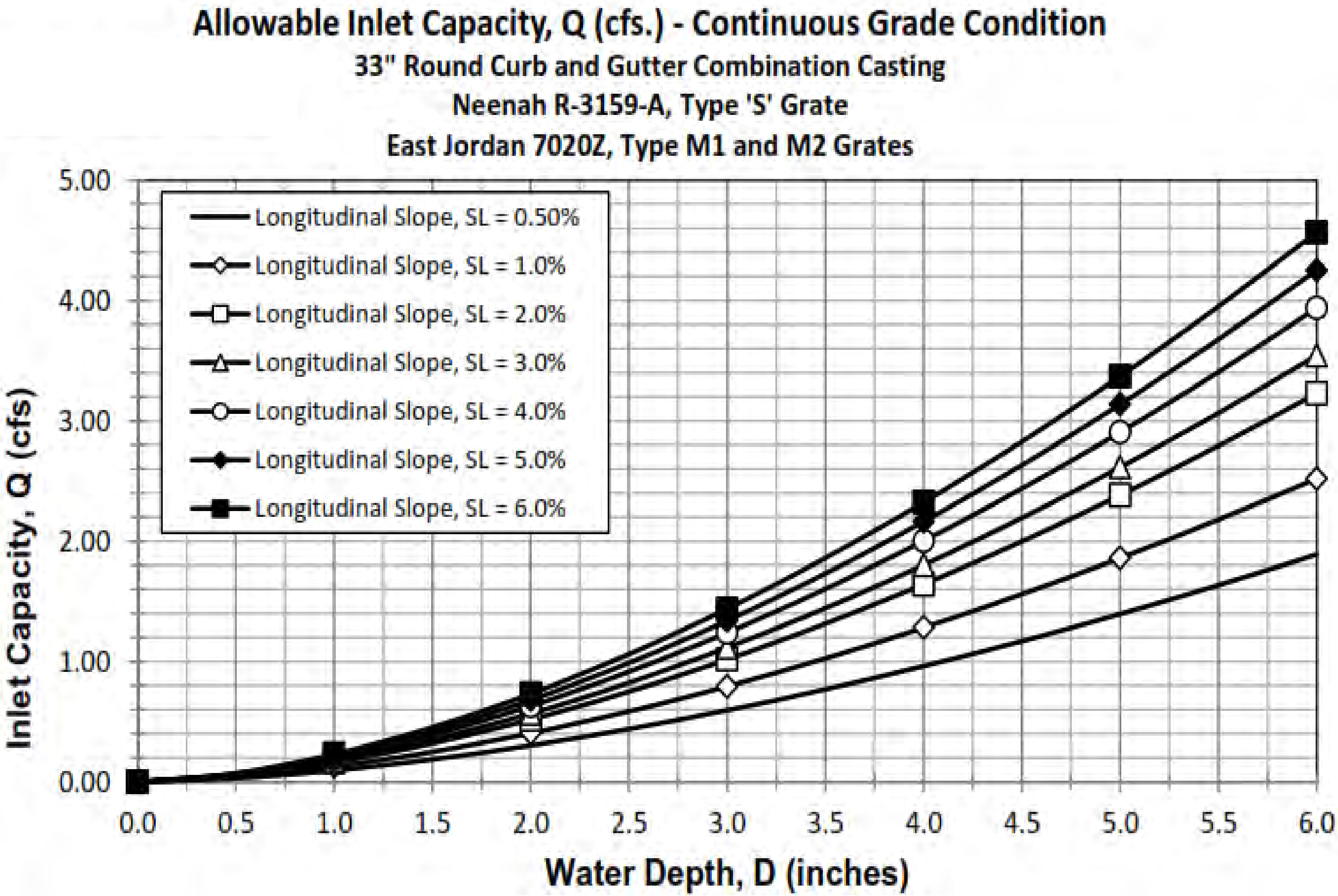
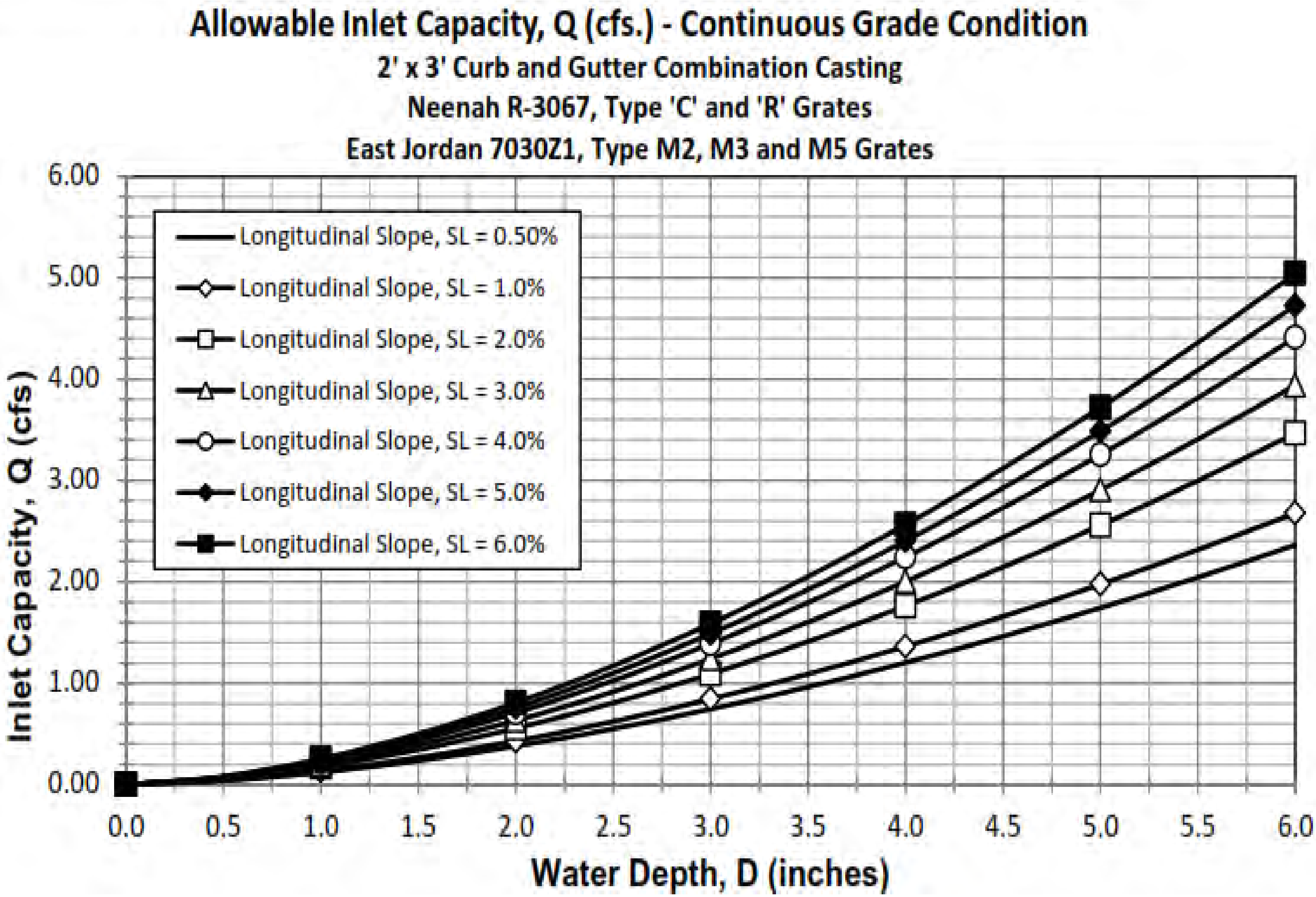


Figure 4-17. Allowable Inlet Capacity Continuous Grade Condition – 2' x 3' Curb & Gutter Combination Casting *(Source: Fort Wayne IN Design Standards Manual)*



4.9.3 Gutter Flow

The capacity of gutter flow in curbed pavement helps determine proper inlet casting and inlet spacing designs. Many factors affect the flow capacity of gutters. These factors work together to provide a safe limit on storm water encroachment into driving lanes and parking areas. Policies for gutter flow are as follows.

Allowable use of streets for storm water flows. Use Tables 4-28 and 4-29 to determine the allowable encroachment into driving lanes for various street types and widths for the 25-year and 100-year events, respectively.

Gutter flow capacity. Use **Equation 4-31** to determine the gutter flow capacity. Note the assumptions below the equation. Note also that the equations refer to the gutter cross section in **Figure 4-18.**

$$Q = \frac{0.56\left(S_X{}^{1.67} S_L{}^{0.50} T^{2.67}\right)}{n} \qquad \textbf{Eq. 4-31}$$

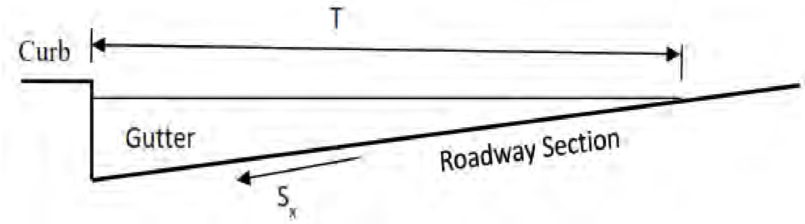
Where:

Q	=	flow (cubic feet per second)
S_X	=	pavement cross slope, (foot/foot)
S_L	=	average longitudinal slope of gutter, (foot/foot)
T	=	top width of flow extending from face of curb to street, (feet)
n	=	Manning's roughness coefficient

Equation assumptions:

- S_x = 2.0% or 0.020 foot/foot
- n = 0.016 (Manning's n values vary depending on situation)
- A minimum of 75% of design flow shall be intercepted by the inlet
- Total gutter width = 1.5 feet (consists of a 6-inch-wide curb and 12-inch-wide gutter section, typically cast-in-place concrete.)
- Maximum curb height = 6 inches
- Maximum allowable gutter flow for the 25-year event is 10 cubic feet per second.
- S_X is equivalent across both the pavement and gutter.

Figure 4-18. Gutter Cross Section



4.10 Culverts

4.10.1 Purpose

A culvert is defined as a conduit for the conveyance of water under a roadway, railroad, or other embankment. In addition to serving hydraulic functions, culverts must also carry overhead loads from traffic and other activities, thereby serving a structural function. Proper culvert design is essential because culverts often significantly influence upstream and downstream flood risks, floodplain management, and public safety.

A culvert, as distinguished from a bridge, is usually covered with embankment and is composed of structural material around the entire perimeter although it can be supported on spread footings with the streambed serving as the bottom.

A bridge is a structure having an opening measured along the centerline of a roadway of more than 20 feet between faces of abutments or spring lines of arches. Multiple barrel box culverts or multiple pipe culverts having an opening of more than 20 feet between the limits of the extreme openings are sometimes classed as bridges.

4.10.2 General Design Policies

The criteria presented in this section shall be used in the design of culverts.

Design storms for public culverts. Publicly owned culverts crossing a roadway shall be designed to convey the peak flow resulting from a 100-year event. Driveway culverts within right-of-way shall convey the peak flow resulting from a 50-year event.

Design storms for private culverts. Privately owned culverts located outside right-of-way and serving areas that do not require detention shall be designed to convey the peak flow resulting from a 50-year event and provisions shall be made to contain the runoff from a 100-year event. Lesser capacities may be considered provided that proper accommodations are provided for on- site storage of the 100-year event.

Required design specifications. The design of culverts shall conform to the methodology described in the Hydraulic Design of Highway Culverts published by the U.S. Department of Transportation's Federal Highway Administration's Publication No. FHWA-HIF-12-026, April 2012 (or current edition), unless otherwise specified herein or by the Director. This design publication is available online at: https://www.fhwa.dot.gov/engineering/hydraulics/pubs/12026/hif12026.pdf.

Required design program. The HY-8 program is the computerized implementation of FHWA culvert hydraulic approaches and protocols and shall be used for culvert design. Available online at http://www.fhwa.dot.gov/engineering/hydraulics/software/hy8/.

Use of ALDOT guidance encouraged. The ALDOT 2014 Standard and Special Drawings for Highway Construction (or current edition) provides valuable culvert design information. The document is available online at: http://alletting.dot.state.al.us/Docs/Standard_Drawings/StdSpecialDrawingsEnglish2014.htm.

Required Manning's coefficient. A Manning's roughness coefficient of 0.013 shall be used to size concrete pipe and box culverts.

Culvert length. Culvert length design shall consider embankment width, installation depth, and embankment slopes.

Culvert material. Culverts shall be a minimum of Class 3 reinforced concrete if the storm sewer:

a. is to be transferred to the City of Birmingham for maintenance;
b. is located in a recorded easement; and/or,
c. conveys offsite storm water runoff through a site.

Culvert materials other than reinforced concrete may be used on systems that do not meet the above criteria.

Box culvert loading. Box culverts shall be designed for American Association of State Highway and Transportation Officials (AASHTO) HS-20 loading in vehicular traffic areas (existing or potential) and HS-15 loading in all other areas.

Backwater. Culverts shall not increase backwater elevations on upstream properties.

Overland flow routes. Emergency overland flow routes shall be checked to assure that backwater resulting from a potentially blocked culvert or intense storm does not flood or damage property. If an emergency overland flow route is not available, culvert flow capacity shall be increased. Sound engineering judgment shall be applied in determining the potential extent of backwater damage and the necessary increase in culvert flow capacity.

Minimum diameter. The minimum diameter for culverts crossing a public roadway shall be 18 inches. The minimum diameter for private driveway culverts within right-of-way shall be 12 inches.

Flow velocity. Both minimum and maximum flow velocities should be considered when designing a culvert.

a. A minimum velocity of 3.0 feet per second when the culvert is flowing partially full is recommended to ensure a self- cleaning condition during partial depth flow.

b. The maximum velocity should not exceed culvert manufacturer recommendations. The maximum velocity should be consistent with channel stability requirements at the culvert outlet.

c. The maximum allowable outlet velocity of culverts, which discharge to an earthen channel, shall be 6 feet per second.

d. As outlet velocities increase, the need for channel stabilization at the culvert outlet increases. If velocities exceed permissible velocities for the various types of nonstructural outlet lining material available, the installation of structural energy dissipaters are required.

Sumped culverts. Circular and elliptical pipes shall be installed with pipe inverts lower than adjacent channel flowline for sumped culverts. Sound engineering judgment shall be applied to determine the depth of sumping. Sumping increases the base flow capacity of circular and elliptical pipes, accommodates the future lowering of the channel, may increase the depth of pipe cover, and in environmentally sensitive areas allows for a natural stream bottom in the pipes.

4.10.3 Structural Design Policies

Loading. All culverts crossing a roadway shall be designed to withstand a minimum HS-20-44 loading as defined by AASHTO. Culverts crossing a railroad shall be designed to withstand an E-80 loading.

Installation depth. Refer to manufacturer specifications or recommendations for installation depth requirements.

Bedding and backfill. Backfill classifications, materials, and methods of compaction shall be in accordance with the City of Birmingham's Standard Specifications for the Construction of Public Works Projects for projects inside of the City limits unless special circumstances warrant otherwise.

Floatation and anchoring. Pipe floatation can occur when the uplift (buoyancy) forces outside the pipe are greater than the downward weight forces on the pipe. This uplift force can be great enough to cause the pipe to bend and dislodge from the embankment. Large diameter, flexible material culverts are more vulnerable to floatation. Anchoring may be achieved using concrete end sections, ties to a concrete footer, or other similar means.

4.10.4 Inlet and Outlet Configuration

General. All culverts, public and private, shall have end treatments such as prefabricated end sections, wing walls and aprons, or headwalls at the inlet and the outlet. The design of end treatments shall consider public safety and erosion control.

Roadside safety. Roadside ditch culverts for commercial and residential drives shall have sloped prefabricated end sections. Headwalls and wing walls are not permitted.

Trash racks. Trash racks should be considered for inlet culvert end treatment where inlet clogging or downstream trash pollution is anticipated due to upstream land use activities. In general, trash racks shall not be used on culvert outlets. However, trash racks may be warranted on outlets in areas where public safety is a concern.

Erosion control. Channel stabilization and erosion control measures shall be utilized at the inlet and outlet of a culvert.

4.10.5 Environmental Considerations

Migrating fish. In channels with a base flow or normal pool, migration of aquatic species should be considered. Culverts should be sumped to maintain a base flow depth through the culvert equal to or greater than the adjacent channel base flow depth. Bottomless culverts may be considered to maintain a natural stream bottom. Where fish migration is a concern, contact the Alabama Department of Conservation and Natural Resources (ADCNR), Wildlife and Freshwater Fisheries Division for culvert design assistance.

4.10.6 Permitting

Culvert installation may require approval and/or permitting from federal, state, or other local agencies. It is the responsibility of the applicant to understand and obtain all required permits. Early coordination regarding permitting and approval is recommended. Each public agency may have design criteria which must be complied with for permitting.

The public agencies who may require approval for culvert design or installation include the following.

- City of Birmingham Department of Planning, Engineering & Permits for work within city street or road right-of-way or within floodplains or floodways.
- ALDOT, District 31 for work within state, federal, or interstate highway rights-of-way.
- Jefferson County Highway Department for work within county road right-of-way.
- Birmingham Park and Recreation Department for work affecting the Greenway, trails, and bicycle system.
- Jefferson County Surveyor's Office for work affecting Jefferson County regulated drains or mutual drains.
- ADCNR for:
  - Early coordination for projects affecting stream channels or wetlands;
  - Stream crossings;
  - Work within a floodway or floodplain; and/or
  - All culverts and bridges, public or private, with a drainage area equal to or greater than 1 square mile.
- Alabama Department of Environmental Management (ADEM) for Early Coordination for projects affecting stream channels including regulated drains.
- United States Army Corps of Engineers (USACE) for Early Coordination for projects affecting wetlands or stream channels including regulated drains.

4.11 Open Channels

By definition, an open channel is a conduit for the conveyance of liquids. Flow in an open channel is open to the atmosphere and driven by gravity.

Open channels for the conveyance of storm water can be natural or constructed. **Natural channels** include rivers, streams, and natural intermittent drainage courses. Investigation and analysis of the capacity of existing natural channels using the USACE Hydrologic Engineering Center River Analysis System (HEC-RAS) is complex and time consuming. Alteration of a natural channel is also regulated and can require permits from the USACE, ADCNR, and ADEM.

Constructed channels include drainage ditches, roadside ditches, swales, bio-swales, and water quality treatment channels. New constructed channels can be excavated or existing constructed channels can be reconstructed as part of a new or altered storm drainage system. Alteration of existing constructed channels might require permits from the City of Birmingham Department of Planning, Engineering & Permits, USACE, ADCNR or ADEM. This section provides information for the design of constructed channels for the conveyance of storm water in Birmingham.

Grass channels. Historically, design criteria for channels considered minimum flow velocity to prevent sedimentation within the channel. However, maintaining a minimum flow velocity may not always be desirable. Grass channels are GIPs or BMPs for storm water quality, depending on their design. In these cases, low velocity and high infiltration is encouraged within the channel. Site designers who plan to design and construct a water quality channel or a grassed swale for purposes of storm water quality shall refer to the appropriate design specification in Chapter 6.

4.11.1 Channel Shape

The site designer shall determine the appropriate shape for a constructed channel using engineering judgement and the following guidance.

4.11.1.1 V-Shaped Channels

V-shaped open channels are used for roadside ditches or swales. These types of channels are not efficient for conveyance of high flows and are generally designed for collection of intermittent surface sheet flow.

4.11.1.2 Dry Water Quality Swale/Enhanced Swale/Drainage Swales

Swales are shallow channels with relatively flat side slopes frequently used in maintained yard areas or fields. Flow in swales is generally intermittent, collecting runoff during and immediately following rainfall events. Swales can also be used as overland flow routes for protection of property if storm water conveyance or detention facilities fail or overflow.

Swales are not necessarily V-shaped channels. Swales can have uniform or variable width bottoms.

4.11.1.3 Trapezoidal Channels

A trapezoid is defined as a quadrilateral figure with two parallel sides. In the case of an open channel, the channel bottom and top of water are regarded as parallel. Channels with rounded bottoms shall be treated as trapezoidal.

Trapezoidal channels can have uniform or variable bottom widths and side slopes. In developed or agricultural areas where land is premium, storm drainage channels are generally designed to be uniform and functional with minimum use of land.

Two-stage open channels are designed with a low flow channel and at a higher elevation a wider second stage channel. Two-stage channels provide in channel storage and reduce flow velocity at higher flow rates.

4.11.1.4 Composite Channel

Composite channels are designed with a low flow channel in combination with additional natural channel features. Composite channels can be utilized as storm water quality best management practices, detention facilities, wildlife habitat, attractive landscape feature, or a combination of the above.

Composite channels may incorporate a low flow, meandering, variable width channel through constructed wetlands, or open pools. The low flow channel may meander through a wider valley which can flood during higher flows. Composite channels can be used with a water control structure or multiple control structures which reduce flow velocity and provide storage during periods of high flow.

Low flow channel and valley side slopes and bottom widths may vary to provide the appearance of a natural topography. Riparian vegetation may be planted for water quality treatment and to provide a naturally appearing landscape. Upland slopes can be planted with prairie grass mixes and native woody species.

4.11.2 General Design

Hydraulic design requirements. Open channels serving storm water conveyances and tributary flows from upstream watersheds shall be designed to convey runoff from a 100-year storm event. Hydraulic design shall be in accordance with Section 4.11.7 that follows.

Side slope requirements. The sides of an excavated channels are sloped to provide stability; channel slopes generally do not exceed 1.5:1. Three to one (3:1) slopes are recommended for grass lined channels.

Freeboard required. Open channels shall convey the 100-year event with two (2) feet of freeboard to the top of the channel bank.

Channel lining design. Channel lining shall be incorporated into the design to prevent scour and erosion and to assure stability of the channel. At minimum, the peak flow from a 25-year design storm shall be used to design channel linings criteria for determining required channel lining type and design criteria are set forth in **Table 4-30**.

Table 4-30. Open Channel Parameters

Channel Lining	Maximum Channel Gradient		Maximum Flow Velocity (ft/sec)	Maximum Side Slope (Hor:Vert)
	Percent	ft/ft		
Grass	3.0	0.0	5.0	2:1
Riprap	10.0	0.1	-	2:1
Concrete	-	-	-	1.5:1*
Manufactured Lining	**	**	**	**

* The concrete lining shall be designed as a structural retaining wall.
** Per manufacturer's specifications.

4.11.3 Side Slopes

Channel side slope design is dependent on several factors including soil stability, available land area for top of bank width, ease of maintenance, and safety. Policies are as follows.

Grass lined channels. Side slopes in grass lined channels shall not exceed 3 feet horizontal to 1 foot vertical (3:1).

Yard swales. Side slopes in swales used to convey storm water through or between residential yards shall not exceed 4:1 for ease of maintenance.

Lining required. Channel side slopes between 1.5:1 and 2:1 shall be riprap lined. Where side slopes are steeper than 1.5:1, the channel slopes shall have a concrete lining, and the concrete lining shall be designed as a structural retaining wall.

4.11.4 Bed Slope (Gradient)

Channel bed slope is the channel bottom gradient or profile grade defined as the ratio of elevation change over length. The channel bed slope is expressed as a percentage or a decimal. Channel bed slopes vary due to existing topography and the design requirements of each storm drainage system. Policies are as follows.

Minimum bed slope. The desirable minimum slope for open channels is 0.5% (.005 foot/foot). This is not always possible to achieve in areas of flat topography. Swales with a gradient less than 1.0% shall be served by an underdrain.

Yard swales. The desirable minimum slope for swales used to convey storm water through or between residential yards is 1.0%. Yard swales with slopes less than 1.0% should be constructed with subsurface drains.

Armoring required. Riprap or rock armor lining is required where channel bottom slope exceeds 3.0% or flow velocity exceeds 5 feet per second. Concrete lining shall be used where channel bottom slope exceeds 10% or flow velocity exceeds 15 feet per second.

4.11.5 Linings

Open channel bottoms and side slopes require stabilization measures to prevent scour and erosion. Grass is the most common method of channel stabilization in areas of flat topography. Other acceptable methods include riparian vegetation, riprap or rock, concrete, or manufactured linings. Policies and guidance related to channel linings are provided below.

Required flow rate. At minimum the peak flow rate from a 25-year storm shall be used to design armored linings for all channels.

Hard armoring required. Riprap or rock lined channels are required where flow velocity might result in bottom or side slope erosion.

Grass lined channels. Grass or vegetation lining is permitted in channel bottoms with slopes not exceeding 3.0% or flows not exceeding 5 feet per second. Grass is permitted on channel side slopes not exceeding 3:1. Armor such as rip rap or rock might be required in areas of grass lined channels where scour or erosion might occur. Areas which might require armor include storm water conveyance outlets, changes in bottom slope grade, bends in channel alignment, or areas where gullies might be formed in side slopes by concentrated flow entering a channel over the bank.

Riprap or rock lined channels. Riprap shall comply with the latest version of the ALDOT Standard Specifications for Highway Construction, Section 610. ALDOT Class 1 or Class 2 riprap may be used for energy dissipaters. The maximum slope for riprap lined channels shall not exceed 10.0%.

Concrete lined channels. Due to the maintenance required, concrete lined channels are permitted only in areas where limited space due to existing development prohibits the construction of grass or riprap lined channels, or where the bed slope or side slopes require concrete lining.

Additional policies are as follows.

- Concrete channel lining shall be steel reinforced ALDOT Class A concrete with a minimum thickness of 5 inches.
- Concrete channel lining shall be designed with lugs where bottom slope exceeds 3%.

Manufactured linings. Manufactured channel linings include concrete revetment, gabions, and Reno mattresses or turf reinforcement mats. Manufactured linings shall be designed and constructed according to the manufacturer's specifications.

4.11.6 Public Safety and Permitting

Public safety. Public safety shall be considered where an open channel presents a potentially dangerous situation to pedestrians or vehicular traffic. Guardrail or fencing may be required for the protection of the public.

Permitting. Open channels are frequently constructed through low lying areas which may contain wetlands. Permitting may be required if wetlands are affected by construction.

4.11.7 Hydraulic Design

4.11.7.1 Uniform Steady Flow Equations

For the purposes of open channel design, flow is usually considered steady and uniform. Given steady uniform flow or a reasonable approximate condition, **Equation 4-32** (Manning's equation) shall be used to calculate the capacity of a channel. Using this equation for gradually varied or rapidly varied flow will result in errors.

$$Q = \left(1.49/n\right) A R_h^{2/3} S_f^{1/2} \qquad \textbf{Eq. 4-32}$$

Where:

Q	=	flow rate (cubic feet per second)
n	=	Manning's roughness coefficient
A	=	flow area (square feet)
R_h	=	hydraulic radius (feet), defined as flow area, A, in square feet divided by the wetted perimeter, P_w, in feet
S_f	=	Friction slope (equal to storm water conveyance slope for uniform flow), foot/foot

4.11.7.2 Flow Regime

A more detailed analysis of an open channel design might be required by the Director if there is concern regarding the flow regime. Flow regime describes the state of flow in an open channel. Critical flow represents the minimum specific energy for a given discharge. The flow depth at critical flow is considered critical depth. Designers must calculate critical depth to classify design flows in the open channel as supercritical or subcritical. To distinguish supercritical and subcritical flow, the Froude number (F_R), which represents the ratio of inertial forces to gravitational forces, is defined by **Equation 4-33**.

$$F_R == \frac{v}{\left(\frac{g * A}{T}\right)^{0.5}} \qquad \textbf{Eq. 4-33}$$

Where:

F_R = Froude number
v = mean velocity (feet per second)
g = acceleration of gravity (32.2 feet per second squared)
A = cross-sectional area of flow (square feet)
T = top width of flow (feet)

For flows near critical depth (Fr=1), small disturbances can cause changes in flow state and unexpected hydraulic jumps. Flow with a Froude number between 0.8 and 1.2 are unstable and must be avoided. Designers should seek to create open channels with subcritical flow. When flow in open channels is subcritical it is relatively easier to handle through bends and flow transitions. Supercritical flow has higher erosive power and hydraulic losses. Due to erosion potential, curves in an open channel with supercritical flow are not practical. A description of each flow regime is provided in **Table 4-31**.

Table 4-31. Flow Regime Classification

Flow Regime	Characteristics
Fr > 1 (Supercritical Flow)	Flow depth controlled by upstream influence, usually critical depth. Flow characterized as shallow with high velocities and steeper slopes. Higher potential for erosion.
Fr < 1 (Subcritical Flow)	Flow depth controlled by downstream influence, usually a ponded area or larger downstream channel. Flow characterized as deep with lower velocities and mild slopes. This flow regime produces most stable open channels.
Fr = 1 (Critical Flow)	Minimum specific energy for a given discharge.

4.12 Energy Dissipation

Energy dissipaters are devices or practices designed to reduce the velocity, energy, and turbulence of flow. Energy dissipaters are required when highly erosive velocities are encountered at the end of culverts or at the bottom of steep slopes. Energy dissipaters include, but are not limited to, riprap aprons, riprap basins, and baffled outlets.

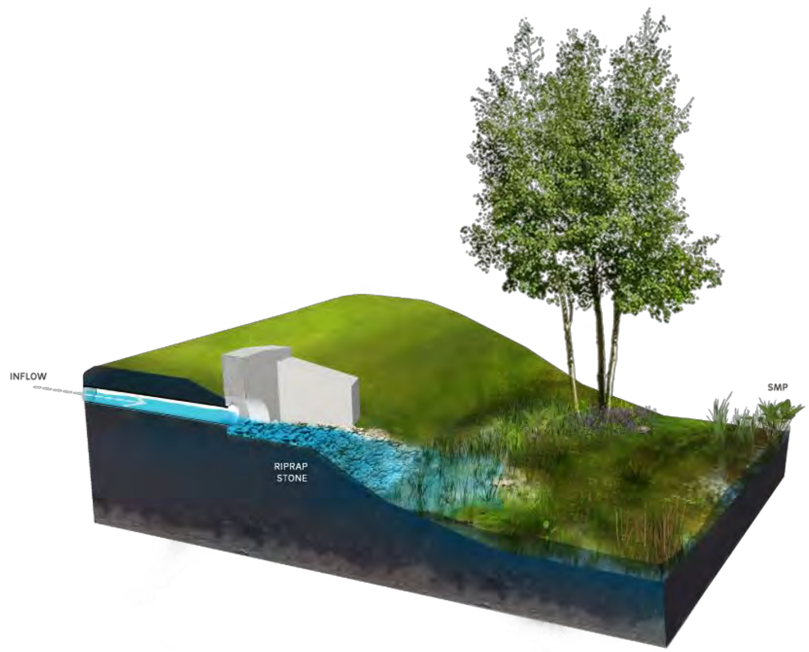
Energy dissipaters are commonly used as an inlet control for bioretention basins, ponds, and wet basins. Depending on the site layout and storm water conveyance design, they may be applicable to media filters. They can be used downstream of other inlet controls that concentrate storm water flow, as well as on steeper slopes, to reduce erosion potential.

In addition to the policies and guidance below, more information on energy dissipation is provided in Chapter 6.

4.12.1 Riprap Aprons

Riprap aprons are commonly used for energy dissipation due to their relatively low cost and ease of installation. A flat riprap apron can be used to prevent erosion at the transition from a pipe or box culvert outlet to a natural channel. Riprap aprons will provide adequate protection against erosive flows provided there is sufficient length and flare to dissipate energy by expanding the flow. An example is provided in **Figure 4-19**.

Figure 4-19. Riprap Apron with Typical Features *(Source: Fort Wayne, IN Design Standards Manual)*



4.12.2 Riprap Basin

A riprap outlet basin is a pre-shaped scour hole lined with riprap that functions as an energy dissipater. Like a riprap apron, a riprap basin can be used to prevent erosion at the transition from a pipe or box culvert outlet to an earthen channel.

4.12.3 Baffled Outlet

Baffled outlets are concrete or fiberglass boxes containing an alternating series of baffles and chambers. In addition to reducing flow velocity and energy, baffled outlets can effectively remove sediment, suspended particles, and associated pollutants from storm water.

4.12.4 Design Policies and Guidance

1. Energy dissipaters shall be designed and sized in accordance with the design procedures in the latest edition of the USACE Hydraulic Engineering Center Circular 14 (HEC-14). HEC-14 includes design information for alternate types of energy dissipaters, such as drop structures and stilling basins.
2. The energy dissipater type selected for the application shall be appropriate for the intended use and for the characteristics of the site such as slope, available area, and landscape aesthetics.
3. A key design issue for energy dissipater is the interface between the end of the dissipater and the adjacent downstream area, which is typically vegetated. The site designer shall indicate the ground cover at this location on the post-construction storm water plan and as-built plan. If this interface area is to be vegetated, the vegetation shall consist of a dense stand of grass (or other ground cover) that is/can be well-established and will withstand periods of flowing water. Turf reinforcement matting may be used at this interface to provide additional structure for vegetation.
4. Vegetation/plantings can be used to obscure views of energy dissipation structures if aesthetics are a concern.

4.12.5 Benefits and Limitations

When designed and installed appropriately, energy dissipaters have the following benefits.

- Reduce velocities of concentrated storm water runoff.
- Reduce erosion potential and allow for more efficient sediment removal efforts, reducing overall maintenance costs and improving GIP/BMP performance.
- Prevent scour that may undermine the structure discharging concentrated storm water runoff.
- Prevent downslope erosion that may create gullies and scour holes.

Poor application, design, or installation will limit the effectiveness of energy dissipaters and potentially cause larger problems resulting in added maintenance. Potential problems include the following.

- X Increased erosion in the GIP, BMP, or downstream channel that potentially leads to sedimentation, clogging, or vegetation damage, and poor storm water quality.
- X Installation difficulties on steep slopes or highly constrained sites.

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Chapter 5. Storm Water Low Impact Development Practices

General Principles

Operationally, economically and aesthetically, the use of LID practices offers significant benefits over treating and controlling storm water downstream.

LID Implementation Process

The City makes every effort to consistently meet clean water standards.

LID Practices

LID practices include a number of site design techniques such as preserving natural features and resources, effectively laying out the site elements to reduce impact, reducing the amount of impervious surfaces, and utilizing natural features on the site.

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5.1 General Principles

When used in the context of storm water management, Low Impact Development (LID) is defined as an approach to land development (both new development and redevelopment) that works with nature to manage storm water as close to its source as possible, ideally using natural hydrologic processes such as infiltration, interception, and evapotranspiration. Storm water LID practices employ principles like preserving and recreating natural landscape features and minimizing effective imperviousness to create functional and appealing site drainage that treats storm water as a resource rather than a waste product. **Reduction of adverse storm water impacts using storm water LID practices should be the first consideration of the site designer for every land development, including redevelopments.** Operationally, economically, and aesthetically, LID practices can offer significant benefits over treating and controlling storm water onsite or downstream. Therefore, feasible opportunities for using these methods should be explored and exhausted before considering the use of the Green Infrastructure Practices (GIPs) or Total Suspended Solids(TSS) Removal Best Management Practices (BMPs) detailed in Chapter 6.

Land developments can be designed to reduce, and sometimes even eliminate, storm water impacts when careful efforts are made to conserve natural areas, reduce impervious cover, and better integrate storm water management techniques. By implementing a combination of these nonstructural approaches, it is possible to reduce the amount of storm water, and therefore pollutants, that are generated from a development after construction. This overall reduction in storm water can yield multiple benefits, such as minimizing costs for infrastructure construction and long-term post-construction maintenance. The *City of Birmingham Comprehensive Plan* and supporting framework plans also encourage these general principles and should be taken into consideration in the preliminary phase of planning a land development, ideally well before the layout of impervious and pervious areas is envisioned.

In general, storm water LID practices are based on the following general goals:

- Early communication and coordination between the City and the development's multi-disciplinary design team;
- Prioritization of infill and redevelopment to capitalize on use of vacant properties and existing infrastructure;
- Management of storm water (quantity and quality) as close to the point of origin as possible resulting in minimized collection and conveyance;
- Prevention of negative impacts that can result from post-development storm water, so that mitigation is unnecessary;
- Utilization of simple, nonstructural methods for storm water management that are lower cost and lower maintenance than structural controls;
- Creation of a multifunctional landscape that can manage storm water and address or benefit other development needs; and
- Reliance on hydrology as a framework for land development design.

Storm water LID practices include several site design techniques such as preserving natural features and resources, effectively laying out the site elements to reduce impact, reducing the number of impervious surfaces, and utilizing natural features on the site for storm water management. The aim of using LID practices is to reduce the environmental impact "footprint" of the site while retaining and enhancing the owner/developer's purpose and vision for the site. Many of the LID practices and concepts can reduce the cost of infrastructure while maintaining or even increasing the value of the property.

The reduction in storm water and pollutants using LID practices can reduce the required peak discharges and volumes that must be conveyed and controlled on a site and, therefore, the size and cost of necessary drainage infrastructure and GIPs. In some cases, the use of LID practices may eliminate the need for structural controls entirely. Hence, LID practices can be viewed as both a water quantity and water quality management tool. Some of the practices described in this section provide incentives and reductions for compliance with Birmingham's storm water performance standards established in Chapter 2 of this manual. Specific storm water LID practices are presented and addressed in detail later in this chapter.

The use of LID practices can also have several other ancillary benefits:

- Reduced construction costs through lower overall costs for land clearing and total infrastructure materials and construction;
- Improved overall marketability and property values;
- More open space for recreation;
- More pedestrian-friendly neighborhoods;
- Protection of sensitive forests, wetlands, and habitats;
- More aesthetically pleasing and naturally attractive landscape;
- Reduced need for irrigation using native plants and/or rainfall storage and reuse;
- Opportunities for education, community involvement, and community stewardship;
- Early identification of storm water management opportunities or obstacles;
- Easier compliance with wetland and other resource protection regulations; and
- Possibility to obtain Leadership in Energy & Environmental Design (LEED) points.

The next section provides insight into the process that should be used to consider and successfully implement storm water LID practices.

5.2 The LID Implementation Process

Figure 5-1 depicts the process that should be used to evaluate and implement storm water LID practices when preparing a land development site design. There are several significant elements in the figure that should be noted by the site designer.

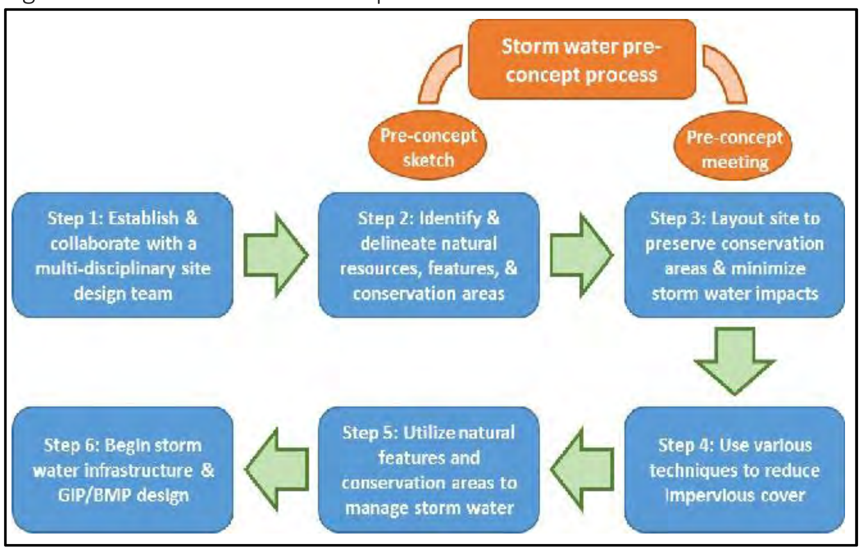
- First, moving step-wise through the process, one can see that successful **LID practice implementation <u>ENDS</u> when a designer begins the analyses and computations for infrastructure design**. Stated differently, all the effort in LID practice planning takes place very early, so that **the site layout is established <u>using</u> storm water LID concepts**. Thus, the site layout will consist of a relative placement to buildings and roads to pervious areas, preserved green spaces, and conservation areas which optimizes natural processes for storm water management.

  This early planning approach is critical for the successful use of storm water LID practices because it strives to fit the development's buildings and pavement to the existing property's topography and hydrology, thus taking advantage of natural features and processes to do the work of storm water management. In contrast, site designers who attempt to fit the existing property to a pre-conceived or "cookie-cutter" layout, or who wait to consider LID practices until after the site grading and layout are established, are not likely to have a high degree of success with LID.

- Note also that Figure 5-1 depicts the relationship between the storm water LID implementation process and Birmingham's storm water pre-concept planning process. The storm water pre-concept process includes the development of a report that characterizes the existing condition hydrology of a potential development site and a collaborative meeting with Birmingham staff to examine site conditions, consider the vision for the future development, and gain perspective on the feasibility of LID practices and GIPs.

Ideally, the outcome of the meeting will be a mutual understanding of the potential storm water management approach for the site and any limitations to the use of specific practices. Based on this understanding, the site designer can proceed with the site layout with inclusion of the LID practices that have been identified as worthy of consideration. Thus, the site design team's participation in the pre-concept process is of value to both the private developer and City staff, and certainly fits within a normal LID implementation process. The pre-concept process is described more fully in Section 5.4.2 and Chapter 2 of this manual.

Figure 5-1. Storm Water LID Implementation Process



Each step in Figure 5-1 is summarized below.

Step 1 – Site Design Team. Step 1 of the storm water LID process involves identifying a multi-disciplinary design team to be used throughout the site storm water planning, design, and construction process. Storm water LID practices and GIPs demand that soil and vegetation be considered design elements for storage and volume reduction. As a result, storm water management design is no longer the sole domain of the civil engineer, and professionals knowledgeable of several key disciplines can add great value to a site design. Such disciplines include hydrology, ecology, landscape architecture, land use planning, soil science, geomorphology, horticulture, and even forestry. This step is further discussed in Section 5.4.1 of this chapter.

Step 2 – Feature Identification. The identification of hydrologic and natural features, conservation areas, and other resources on a development site is vital to understanding the existing hydrology of the area and how such features can serve a storm water management function after development. Features to be inventoried include undisturbed forest areas, stream buffers, and steep slopes. A full list of items that should be inventoried is included in the pre-concept sketch checklist, which is provided in Appendix B.

Step 3 – Maximize Natural Areas. After inventory of the site's hydrologic and natural features, the site layout can begin to take shape as the site design team collaborates. This is the ideal time to hold the pre-concept meeting with City staff. Several storm water LID practices can be considered in this step to maximize preservation of these features, including the avoidance of floodplains and stream buffers, location of buildings and pavement on soils that are less porous, minimal plans for clearing/grading, and use of an open space layout.

Step 4 – Minimize Impervious Cover. Maximization of preserved natural areas is then followed by application of LID practices that target the reduction of the overall imperviousness of the development site. These techniques directly minimize the storm water that will be generated from the development. Such practices include roadway width minimization and reducing parking and building footprints.

Step 5 – Use Preserved Natural Features. As the site layout is established, the site designer should also consider those LID practices that target the use of preserved natural features, conservation areas, and other pervious surfaces for the management of storm water that is discharged from impervious surfaces. For example, discharging storm water from a small parking area into a well-draining forested area or using natural, vegetated swales to convey storm water are both less expensive storm water management options than the construction and maintenance of ditches and pipes.

Step 6 – Begin Storm Water Design. Once all storm water LID practices are considered and exhausted, the site designer should have a site layout that effectively minimizes the volume (and in many cases the peak discharges) of storm water that will be discharged from the development and maximizes the use of less costly, lower maintenance techniques to manage storm water. At this point, the site designer can begin the data preparation and analyses required for the design and specification of the man-made on-site storm water drainage system, GIPs, and BMPs.

5.3 Overview of LID Practices

The storm water LID practices addressed in this chapter are listed in **Table 5-1**. The table groups the practices into three major categories that can align with Steps 1, 2, and 3 of the LID implementation process presented in the previous section. These categories are described after the table.

More detail on each of the LID practices in the table is provided on the LID Practice Fact Sheets that comprise Section 5.4 of this chapter. The fact sheets are one to two-page guides that explain the key benefits of each practice, identify where incentives may be available, and provide examples and details on how to apply them in land development design.

Table 5-1. Storm Water LID Categories and Practices

Summary Description
Early Coordination, Collaboration, and Communication ❖ Work with multi-disciplinary design team (civil engineers, landscape architect, ecologist, etc.) ❖ Participate in the storm water pre-concept process
Conservation of Natural Features and Resources ❖ Tree and stream buffer protection and restoration *(incentive available)* ❖ Soil Restoration *(incentive available)*
"Build with the Land" Design Techniques ❖ Implement Retrofits *(incentive available)* ❖ Reduce Impervious Surface *(incentive available)* ❖ Redevelopment and Infill *(incentive available)*
Greenspace Enhancement ❖ Complete Streets ❖ Greenway Connections ❖ Pocket Parks

5.3.1 Early Coordination, Collaboration, & Communication

As mentioned previously, early coordination, collaboration, and communication is critical to successful implementation of LID practices. For this category, two LID practices are recognized: use of a multi-disciplinary design team and participation in the storm water pre-concept process. Early coordination with engineering, science, and planning professionals who know storm water can result in an innovative site design that optimizes multi-functional spaces and storm water designs and potentially minimizes the need for costly grading and storm water infrastructure.

5.3.2 Conservation of Natural Features and Resources

Conservation of natural features is integral to the success of a LID site design. This category of LID practices involves the identification and preservation of natural features and hydrologic resources on a site for the purposes of reducing storm water volume, pollutants, and peak flow; providing storm water storage; reducing flooding; preventing soil erosion; and promoting infiltration and evapotranspiration. Note that all of these purposes align fully with the storm water policies and performance standards that are established in Chapter 3. Thus, the conservation of natural features and resources should be a first thought for site design teams who are focused on ease of compliance with storm water performance standards. Some of the natural features that should be considered are listed below.

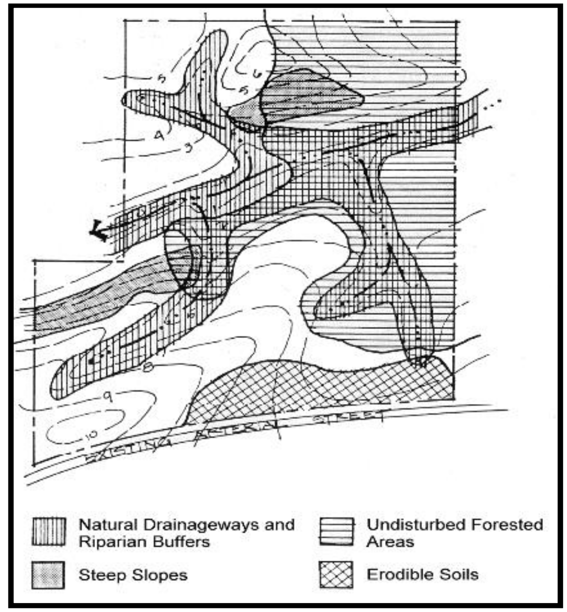
- ✓ Areas of undisturbed vegetation
- ✓ Floodplains and riparian areas
- ✓ Ridgetops and steep slopes
- ✓ Natural drainage pathways
- ✓ Intermittent and perennial streams
- ✓ Wetlands
- ✓ Aquifers & recharge areas
- ✓ Soils
- ✓ Shallow bedrock
- ✓ High water table
- ✓ Other natural features or critical areas

Storm water LID techniques that conserve natural features and resources include the following:

- ❖ Preserve undisturbed natural areas,
- ❖ Preserve riparian buffers,
- ❖ Avoid floodplains, and
- ❖ Avoid steep slopes.

Mapping of natural features is typically done through a comprehensive site analysis and inventory before any site layout design is performed. From this site analysis, a concept plan for a site can be prepared that provides for the conservation and protection of natural features. An example of a natural features map is shown in **Figure 5-2**.

Figure 5-2. Example of Natural Feature Map *(Source: MPCA, 1989)*



5.3.3 "Build With the Land" Site Design Techniques

After a site analysis has been performed and conservation areas have been delineated, there are numerous opportunities to reduce both storm water quantity and quality impacts as the site layout is prepared. The storm water LID practices that can be used at this stage primarily deal with the location and configuration of impervious surfaces or structures on the site and their location relative to natural features and preservation/conservation areas. These LID practices include the following.

- ❖ Fit the design to the terrain,
- ❖ Locate development in less sensitive areas,
- ❖ Reduce limits of clearing and grading,
- ❖ Utilize open space development, and
- ❖ Consider creative development design.

The goal of techniques that "build with the land" is to position the elements of the development project in such a way that the site design (i.e., placement of buildings, parking, streets and driveways, lawns, undisturbed vegetation, buffers, etc.) is optimized for effective storm water management. That is, the site design takes advantage of the site's natural features, including those placed in conservation areas, as well as any site constraints and opportunities (topography, soils, natural vegetation, floodplains, shallow bedrock, high water table, etc.) to prevent both on-site and downstream storm water impacts.

Figure 5-3 shows a development that has utilized several "build with the land" site design techniques in its overall layout and design. In the figure, the rough site layout (right) seeks to: 1) **reduce the limits of clearing and grading** to only the area needed for impervious surfaces, setbacks, infrastructure, and utilities; and 2) **locate the development in less sensitive areas** by preserving the forested buffer that bounds a stream located to along the left boundary of the property.

Figure 5-3. Site Layout Utilizing "Build with the Land" Techniques

5.3.4 Greenspace Enhancement

The disappearance of undeveloped greenspace can be a negative consequence of development. An overall decrease in natural and pervious land area can lead to an increase in storm water runoff and a decrease in storm water quality. Greenspace also contributes to livability and is an important community asset that has been shown to promote fitness, health benefits, and community involvement. Creating connected and livable development promotes living and working in Birmingham and encourages investment. These overarching goals are stated in the *City of Birmingham Comprehensive Plan*. Storm water LID practices that promote the use of green spaces should be considered for all projects. These practices include the following, which are described in detail later in this chapter.

- Complete Streets
- Greenway Connections
- Pocket Parks

Figure 5-4 provides an example of a greenspace enhancement strategy used in an urban environment.

Figure 5-4. Pocket Park Incorporated into an Urban Area

5.3.5 Other Design Techniques

Other common design techniques can be used to maximize a site designer's success using the storm water LID practices itemized above. These techniques are listed in **Table 5-2**, along with the Birmingham resource document that can be used to assess the technique's feasibility for a particular site design. These site design techniques target the reduction of impervious surfaces (generally, rooftops and pavement) and the use of natural features to manage storm water that is generated from the impervious surfaces that are constructed. The site design team can consult Section 5.4 and Chapter 6 of this manual to learn more about techniques that involve the use of GIPs.

Table 5-2. Common Site Design Techniques Used to Enhance the Success of Storm Water LID Practices

Site Design Technique	Resource Document
Reduction of Impervious Cover ❖ Reduce roadway lengths & Widths ❖ Reduce building footprints ❖ Reduce the parking footprint ❖ Reduce setbacks and frontages ❖ Use fewer or alternative cul-de-sacs ❖ Create parking lot storm water "Islands"	*Birmingham Zoning Ordinance* *Conservation Subdivision & Cottage Development Ordinance*
GIPs that Reduce and Disconnect Impervious Surfaces* ❖ Green roof ❖ Permeable paver system, pervious concrete, porous concrete ❖ Downspout disconnection	*City of Birmingham Post Construction Storm Water Design Manual,* Chapter 6
Utilization of Natural Features for Storm Water Management ❖ Retain buffers and undisturbed areas ❖ Use natural drainageways instead of storm sewers ❖ Use vegetated swale instead of curb and gutter ❖ Use site reforestation to permanently restore a more advantageous hydrologic condition* ❖ Use soil restoration practices to improve native soils* ❖ Drain rooftop runoff to pervious areas	*City of Birmingham Post Construction Storm Water Design Manual,* Chapter 5, Section 5.4 *City of Birmingham Post Construction Storm Water Design Manual,* Chapter 6

* Incentive available for use of these techniques. See Chapter 3 for more information on design incentives.

5.4 Storm Water LID Practice Fact Sheets

Section 5.4 provides fact sheets for the storm water LID practices listed in Table 5-1. Each of the fact sheets includes an identification and description of the practice, any design or community improvement incentives that can be realized by its use, a discussion of practice benefits, and guidance on the planning and physical feasibility of the practice.

With the exception of Participation on the Storm Water Pre-Concept Process, all of the LID practices discussed in the following pages are not mandatory requirements for storm water management in Birmingham. However, each of these practices, along with the additional techniques listed in the previous section are strongly encouraged by the Birmingham Department of Planning, Engineering & Permits. Not only can implementation of these practices and techniques potentially save land development costs and increase property values, but many of them can also provide larger community benefits such as cleaner water resources, long-lasting, sustainable developments, and opportunities for enjoyable private and public spaces.

With greater interest in storm water LID practices across the globe, significantly more information and ideas for all the practices discussed in the following pages can be found on the internet. The reader is also encouraged to contact the Department of Planning, Engineering & Permits for questions and assistance on local opportunities.

References

Alabama Department of Environmental Management (ADEM), in cooperation with the Alabama Cooperative Extension System and Auburn University. *Low Impact Development Handbook for the State of Alabama*.

Bhamarchitect's Blog. *Exploring built/unbuilt Birmingham*. Tach Archives: 20th Street. Posted on October 9, 2015.

City of Birmingham, Alabama. *2012 City of Birmingham Comprehensive Plan*, 2012.

5.4.1 Multi-Disciplinary Design Team

Above: Early engagement of the site design team can benefit the development project through innovative designs that can save money for construction and maintenance and provide long-term value to the property owner by serving multiple functions for the development.

Description:

A multi-disciplinary design team is used throughout the site storm water planning, design, and construction process to optimize multi-functional spaces and storm water designs and potentially minimize the need for costly grading and storm water infrastructure. The members of the multi-disciplinary design team need to be selected based on the technical needs of the site and may include storm water managers, engineers, hydrologists, ecologists, landscape architects, land use planners, soil scientists, geomorphologists, horticulturalist, and foresters.

Benefits:

With the implementation of LID practices and GIPs, storm water management design is no longer the sole domain of the civil engineer and a multi-disciplinary approach is needed. The main benefits of utilizing a multi-disciplinary design team include:

- Optimization/maximization of multi-functional LID practices and GIP designs;
- Robust understanding of how local, state, and federal requirements can be creatively met;
- Reduction of the use of, and costs associated with, constructed storm water GIPs and infrastructure;
- More robust storm water design and lower maintenance storm water management system; and
- Preservation of the site's natural character and aesthetic features.

Also refer to the following chapter in the *Alabama LID Handbook* for additional information.

- **Chapter 3: Low Impact Development and Community Planning**

Planning and Physical Feasibility:

Impervious surfaces, pervious surfaces, soil, and vegetation are multi-functional site elements which must comply with design specifications to ensure their proper storm water function. As a result, a number of other technical disciplines are training professionals on storm water management. These include engineering, hydrology, ecology, landscape architecture, land use planning, soil science, geomorphology, horticulture, and forestry.

Table 5-3 presents the disciplines and knowledge of a well-rounded site design team. While all of these disciplines may not be necessary for every site design, developers who use multi-disciplinary teams to craft a site's storm water management approach can often produce more cost-effective, yet highly functional drainage designs.

Table 5-3. Site Design Team Disciplines and Relevant Skills

Discipline	Storm Water Design & Construction Knowledge
Engineer	Hydrology, hydraulics, infrastructure design, GIP design, storm water quality and quantity control, design plan preparation
Landscape Architecture	Multi-functional space design, open space function and design, hydrology, landscape design, planting templates
Soil Science	Soil health, profiles, textures, porosity, storage capacity, restoration techniques
Horticulture	Functional landscape planning, local temperate conditions, plant varieties and needs, native plants, plant/soil health, stream buffer restoration, and long-term plant management
Forestry and Ecology	Existing tree stand management, stream buffer restoration/enhancement, reforestation, wildlife/pest management
Geomorphology	Stream restoration, stream bank stability, and management in a built environment

At a minimum, the site design team should include an engineer and landscape architect. However, expanding the team beyond these professionals to those identified in Table 5-3 will likely provide substantial benefits, as the team can better maximize the use of natural features for storm water management, possibly minimizing constructed features and their associated construction and maintenance costs. All team members should be knowledgeable of, and preferably experienced in, storm water management mechanisms, LID approaches, and green infrastructure practices. Local technical knowledge is preferred, and the redevelopment project should be discussed with the City early in the design process. Refer to Chapter 2 for more information on participating in the pre-concept planning process. The following tips can aid in facilitating the use of a multi-disciplinary design team:

- Involve the whole team very early in the process, ideally before the site layout is developed
- Ensure that the team stays involved throughout design and construction to ensure the protection of LID practices and the proper design and construction of GIPs.

5.4.2 Pre-Concept Planning Process

Above: The pre-concept sketch and conference is an opportunity to identify any opportunities or limitations for LID and GIPs.

INCENTIVES

Utilizing the pre-concept process benefits both the developer and the community.

Early interaction with City staff in the pre-concept meeting can result in more efficient reviews of the storm water management.

REQUIREMENTS

Participation in the pre-concept process prior to submittal of a post-construction storm water plan is required in Birmingham. Refer to Chapter 2, Section 2.3 for policies pertaining to the process.

Description:

The *City of Birmingham Post Construction Storm Water Ordinance* requires the submittal of the pre-concept sketch and attendance at the pre-concept conference. This process does not require design calculations or analyses, nor does it result in a plan approval. Rather, the process is used to characterize the hydrologic aspects of the property in its existing condition with the objective of optimizing the future on-site storm water system design and plan review process. Applications for a Storm Water Post Construction Permit will not be considered without proof that the pre-concept process has occurred for the proposed development.

Benefits:

The pre-concept sketch and conference determines the opportunities and limitations of the site in terms of the use of GIPs. The process occurs early in the site planning process and aims to identify the site hydrology, minimize impervious surface, maximize the use of LID practices, and minimize the need for constructed drainage features. The main benefits of utilizing a multi-disciplinary design team include:

- Early identification of opportunities or limitations for LID and GIPs;
- Optimize the storm water infrastructure design by taking full advantage or avoiding natural hydrologic features;
- Potentially reduce grading, construction, and maintenance costs through early planning of storm water LID practices; and
- Early interaction with City staff can result in more efficient development plan reviews, potentially reducing plan approval times.

Also refer to the following chapter in the *Alabama LID Handbook* for additional information.

- **Chapter 3: Low Impact Development and Community Planning**

Planning and Physical Feasibility:

Storm water management should be comprehensive and designed to achieve multiple storm water objectives Preparation of a pre-concept sketch will include the identification and location of features of the development that are important for effective storm water management. These features include, but are not limited to, land cover, hydrologic soil groups, streams, steep slopes, sinkholes, floodplains, bedrock, and existing on-site and adjacent manmade features or storm water systems. Environmentally impaired waters (due to pollutants) and environmentally-sensitive areas (e.g., due to the presence of threatened or endangered species) will also be included.

The pre-concept sketch is required early in the site planning process, ideally before a site design is created for a future land development and definitely before clearing, grading, and construction begin. Early preparation is advantageous for a number of reasons:

- An early understanding of the site's hydrology can reveal potential opportunities to naturally reduce storm water volumes using non-structural LID techniques and structural GIPs. In turn, natural reduction of storm water volumes can potentially decrease the size, cost, and maintenance of the future onsite storm water system.
- A pre-concept sketch can be useful for site layout planning by allowing the site designer to optimize the location of impervious areas (buildings and pavement), GIPs, and BMPs based on the site's natural vegetation and soils. This early planning can significantly increase the development's ability to meet storm water control standards using less costly and more natural approaches.
- A pre-concept sketch allows both the site designer and city plan reviewers to identify and understand very early in the site planning process any limitations to LID and GIPs that may exist. This early recognition can result in the avoidance of design analyses (and associated costs) for unfeasible storm water practices and can allow a more efficient design and plan review experience.
- A pre-concept sketch and conference can allow the site designer and city plan reviewers to identify the potential need for additional data or information to support the eventual design, thus putting everyone "on the same page" and facilitating a more efficient design and plan review process.

Left: Identification and mapping of existing land cover and other hydrologic features on the pre-concept sketch can help to identify opportunities and limitations to natural storm water management. Such features include streams, steep slopes, soil types, and karst areas.

5.4.3 Reduce Impervious Area

Above: Permeable pavers reduce the impervious surface of parking lots and provide a multi-functional value to the developer.

Description:

The practices of reducing and disconnecting impervious surface increase the rainfall that infiltrates into the ground. Impervious areas should be reduced by maximizing landscaping and using green roofs and 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. Runoff from remaining impervious surfaces should be directed to pervious areas and GIPs.

Benefits:

Minimizing impervious surface benefits both the City, the developer, and the community. Less impervious surface means less storm water runoff to manage both onsite and downstream. Reducing and promoting green space can also facilitate recreational and community activities and enhance people's quality of life. The main benefits of reducing impervious surface include:

- A holistic approach to storm water management that minimizes water velocity, run-off, and storm water pollutants;
- Less storm water runoff to manage with onsite GIPs;
- Reduction of on-site erosion and associated maintenance;
- Reduction in the size and cost of storm water management practices and storm water infrastructure; and
- Increased green space and improved aesthetics.

Also refer to the following resources for additional information.

- ***City of Birmingham Post Construction Storm Water Design Manual*, Chapter 6, Sections 6.6, 6.10, and 6.11**
- ***Alabama LID Handbook,* Chapter 3**
- ***The City of Birmingham Comprehensive Plan***

Planning and Physical Feasibility:

Total site impervious surface is minimized through the use of the following GIPs and design elements:

- Installation of green roofs (see Chapter 6, Section 6.10)
- Using porous pavements where permitted (see Chapter 6, Section 6.11)
- 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 developers to increase the number of floors in a building (increase the vertical density) instead of the building's impervious footprint

Infiltration of runoff from impervious surfaces is maximized through use of the following GIPs and design elements:

- Direct roof downspouts to vegetated areas, bioretention, cisterns, or planter boxes, and routing runoff into vegetated swales instead of gutters (see Chapter 6, Section 6.6)
- Install curb cuts to convey storm water into vegetated areas such as roadside swales, parking lot islands, or bioretention areas.
- Convey storm water to bioretention and urban bioretention areas (see Chapter 6, Sections 6.3 and 6.4).
- Convey storm water to other GIPs, as appropriate for onsite storm water management (see Chapter 6).

Above: Utilizing a green roof not only helps reduce the impervious surface foot print of site development, but also provides other benefits including a reduction in heating and cooling. Depending on design, the roof can also become an aesthetic amenity to building occupants or for adjacent taller buildings and can provide habitat for desired wildlife. *(Photos courtesy of Nashville-Davidson County Metro Water Services.)*

5.4.4 Redevelopment and Infill

Above: Downtown Birmingham is experiencing a surge in redevelopment with more attractive live, work, play spaces. Above is a rendering of Birmingham's Pizitz Building after renovation. *(Credit: Bayer Properties)*

Description:

Urban redevelopment or infill is defined as new development that is sited on vacant or undeveloped land within an existing community and that is enclosed by other types of development. The term "urban infill" illustrates that the existing area is mostly built-out and what is being built is "filling in" the gaps. The term refers to building single-family homes in existing neighborhoods, building multi-family homes in existing neighborhoods, and building new development in commercial, office, or mixed-use areas.

Redevelopment and infill development includes:

- Developing one or more areas on an undeveloped or underutilized site within an existing, established urban area;
- Redeveloping an existing neighborhood;
- Subdividing an existing lot into two or more building lots and developing or redeveloping the newly created lots; and
- Demolishing an existing structure on a lot and building a new structure in its place.

Benefits:

Through the strategies identified in the *City of Birmingham Comprehensive Plan*, the City is actively engaged in identifying areas that would benefit from redevelopment and working to remove obstacles and incentivize redevelopment due to its numerous benefits. These benefits arise from increasing the density of where people live, work, shop, and conduct business. Positive results are seen through less transportation and commuting costs, less required infrastructure, and less vacant properties. The main benefits of redevelopment and infill development are listed below.

- More efficient use of existing infrastructure such as: roads, sidewalks, water, sewer, storm sewers, and electric lines;
- Lower costs of public services such as: schools, police, fire, and ambulance service;
- Better use of urban land supplies while reducing consumption of forest and agricultural land. This, in turn, facilitates conservation of non-urban land.;

- Increased access of people to jobs and jobs to labor force;
- Less time, money, energy, and air pollution associated with commuting;
- Replacement of brownfields, abandoned industrial areas, and vacant buildings with functioning assets;
- Stronger real estate markets and property values;
- Renewal of older areas of the City; and
- Support of cultural, arts, educational and civic functions, such as museums, theaters, and universities by locating new businesses near these attractions

Also refer to the following chapter in the *Alabama LID Handbook* for additional information.

- **Chapter 3: Low Impact Development and Community Planning**

Above: Railroad Park is an excellent example of how an infill project designed to be the "living room of the city" and a green space destination spurred a flurry of redevelopment projects and new businesses around the area.

Planning and Physical Feasibility:

Discuss the redevelopment project with the City early in the design process. Refer to Sections 5.4.1 and 5.4.2 for more information on using a multi-disciplinary design team and participating in the pre-concept plan process. The following tips can aid in planning redevelopment and infill projects.

- Work with existing topography, street and sidewalk layouts, and utilities to accommodate building and parking areas.
- Incorporate mixed use and multi-level buildings to optimize usable space.
- Orient buildings toward the street to promote walkability and an attractive streetscape. Provide easy building access for pedestrians.
- Look for opportunities for shared parking, mass transit use, and bicycle parking.
- Reduce the visual impact of new development on established neighborhoods by incorporating and enhancing existing neighborhood elements such as building details, massing, proportions, materials, and landscaping.
- Provide activity and interest along the street. This can be achieved through design features such as large display windows, highlighted entrances with architectural elements, and landscape and hardscape features.
- Increase visibility of businesses from the street for both pedestrians and drivers.

5.4.5 Tree and Stream Buffer Preservation and Restoration

Above: The use of native vegetation and trees in stream buffers and reforested areas will greatly improve the successful growth of the plants and will enhance the value of the area to the surrounding environment.

Description:

Trees and stream buffer vegetation perform important natural functions including: slowing runoff velocities, creating diffuse flow, and reducing non-point source pollution. Tree and stream buffer protection and restoration refer to the practices of maintaining and restoring native vegetation and its benefits to storm water. Trees, shrubs, and other native vegetation are planted or protected to restore areas to their pre-development conditions. The process can be used to establish or maintain mature native plant communities (e.g., forests) in pervious areas on disturbed sites or in buffer areas adjacent to development sites.

Benefits:

The benefits of tree and stream buffer protection and restoration include:

- Restoring pre-development hydrology on development sites and reducing post-construction storm water runoff rates, volumes, and pollutant loads;
- Restoring habitat for priority plant and animal species;
- Stabilizing stream banks and prevents erosion; and
- Providing attractive scenery for the development.

Also refer to the following chapters in the *Alabama LID Handbook* for additional information.

- **Chapter 2: Site Selection**
- **Chapter 11: Riparian Buffers**

Planning and Physical Feasibility:

Mature plant communities intercept rainfall, increase evaporation and transpiration rates, slow and filter storm water runoff, and help improve soil porosity and infiltration rates which leads to reduced post-construction storm water runoff rates, volumes, and pollutant loads. The site reforestation/revegetation process can also be used to provide restored habitat for high priority plant and animal species.

Impacts to natural features should be minimized by reducing the extent of construction and development practices that adversely impact predevelopment hydrology functions. This includes:

- 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 stream buffers along both sides of streams.
- Preserving sensitive environmental areas, historically undisturbed vegetation, and native trees.
- Conforming to watershed, conservation, and open space plans.
- Help create contiguous, interconnected green infrastructure corridors on development sites by connecting reforested or revegetated areas with one another and with other primary and secondary conservation areas through the use of nature trails, bike trails, and other greenway areas.

General Planning and Design

- Reforested/revegetated/preserved areas shall have a contiguous area of 10,000 square feet or more.
- Reforested/revegetated/preserved areas shall not be disturbed after construction (except for disturbances associated with landscaping or removal of invasive vegetation).
- Reforested/revegetated/preserved areas shall be protected, in perpetuity, from the direct impacts of the land development process by a legally enforceable conservation instrument (e.g., conservation easement, deed restriction).

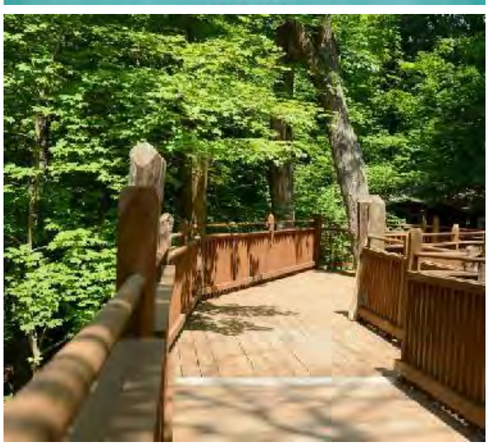
Landscaping

- A soil test shall be performed to determine what type of vegetation can be supported by the soils in the area to be reforested/revegetated and/or what soil amendments will be required.
- A landscaping plan shall be prepared by a qualified licensed professional for all reforested/revegetated areas.
- Landscaping commonly used in site reforestation/revegetation efforts includes native trees, shrubs, and other herbaceous vegetation. Because the goal of the site reforestation/revegetation process is to establish a mature native plant community (e.g., forest), managed turf cannot be used to landscape reforested/revegetated areas.
- Methods used for site reforestation/revegetation shall achieve at least 75% vegetative cover one year after installation.
- A long-term vegetation management plan shall be developed for all reforested/revegetated/preserved areas. The plan shall clearly specify how the area will be maintained in an undisturbed, natural state over time. Plan shall include method for watering during plant establishment period of one to two years. Turf management is not considered to be an acceptable form of vegetation management. Consequently, only reforested/revegetated areas that remain in an undisturbed, natural state are eligible for storm water incentives (i.e., pervious areas consisting of managed turf are not eligible).

Examples of the use of reforestation and stream buffers in urban developments, along with several other LID practices are presented on the following page.

Reforestation & Stream Buffer Examples:

Top left: Seattle, WA. Thornton Place before redevelopment. The abandoned lot was in a blighted area. Thornton Creek ran under the impervious area. *Source: Landscape Architecture Foundation.* Middle left: Land use map for Thornton Place multi-use redevelopment, circa 2008. Note the plans for a buffer along the stream, creating a "water quality channel". *Source: Seattle Condos and Lofts.com*. Top right: Thornton Place after redevelopment, as seen from the walkway through the stream buffer. *Source: Wikimedia Commons*.



Bottom left: Cincinnati, OH. One of the nation's very first urban reforestation projects, Mt. Airy Forest is the largest within the Cincinnati park system at 1,459 acres. It consists of varied topography and landscapes, including ridges, wooded hillsides, ravines, creeks, a lake, and open meadows, and includes walking trails, boardwalks, and bridal paths. *Source: CincinnatiRefined.com.* Bottom right: Austin, TX. The Festival Beach Food Forest is Texas's first food forest located on park, school, and residential properties near the Colorado River. It includes a variety of fruit and nut trees, and many other types of plants, bearing fruits, vegetables, and herbs. *Source: AmericanForests.org*.

5.4.6 Soil Restoration

Above: Soil amendments, such as compost, improve vegetation heath and storm water infiltration

Above: Tilling to a depth of at least 18 inches is necessary for restoring compacted soils. After tilling, protect the area from encroachments by vehicles and heavy equipment to avoid re-compacting the soil.

Description:

Soil restoration refers to the process of tilling and adding compost and other amendments to soils to restore them to their predevelopment conditions, which improves their ability to reduce post-construction storm water runoff rates, volumes, and pollutant loads. The soil restoration process can be used to improve the hydrologic conditions of pervious areas that have been disturbed by clearing, grading, and other land disturbing activities.

Organic compost and other amendments can be tilled into soils in these areas to help create healthier, un-compacted soil matrices that have enough organic matter to support a diverse community of native trees, shrubs, and other herbaceous plants.

Soil restoration can also be used to increase the storm water management benefits provided by other GIPs on sites that have soils with low permeability (i.e., hydrologic soil group C or D soils). The soil restoration process can be used to help increase soil porosity and improve soil infiltration rates on these sites, which improves the ability of these and other low impact development practices to reduce post-construction storm water runoff rates, volumes, and pollutant loads.

Benefits:

Soil restoration helps restore pre-development hydrology, which implicitly reduces post-construction storm water runoff rates, volumes and pollutant loads. The benefits of soil restoration include:

- Restoration of predevelopment hydrology on development sites and reduces post-construction storm water runoff rates, volumes, and pollutant loads; and
- Promotion of plant growth and improvement of plant health, which helps reduce storm water runoff rates, volumes, and pollutant loads.

Also refer to the following resources for additional information.

- **Remainder of the *City of Birmingham Post Construction Storm Water Design Manual***
- ***Alabama LID Handbook*, Chapter 2 (Site Selection)**

Planning and Physical Feasibility:

Soil restoration is ideal for use in pervious areas that have been disturbed by clearing, grading, and other land disturbing activities and/or have soils with low permeability (i.e., hydrologic soil group C or D). Soil restoration should not be performed in areas that have undisturbed, permeable soils (i.e., hydrologic soil group A or B).

Planning and Design Guidance and Policies:

- To the degree possible, buildings, pavement, and construction should be located on the least porous and/or previously disturbed soils.
- Limit soil compaction by: reducing disturbance through design and construction practices; limiting areas of access for heavy equipment; avoiding extensive and unnecessary clearing and stockpiling of topsoil; and maintaining existing topsoil and/or using quality topsoil during construction.
- To avoid damaging existing root systems, soil restoration shall not be performed in areas that fall within the drip line of existing trees.
- Compost shall be incorporated into existing soils, using a rototiller or similar equipment, to a depth of 18 inches and at an application rate necessary to obtain a final average organic matter content of 8%-12%.
- Only well-aged composts that have been composted for a period of at least one year shall be used to amend existing soils. Composts shall be stable and show no signs of further decomposition.
- Composts used to amend existing soils shall meet the following specifications (most compost suppliers will be able to provide this information):
  - Organic Content Matter: Composts shall contain 35% to 65% organic matter.
  - Moisture Content: Composts shall have a moisture content of 40% to 60%.
  - Bulk Density: Composts shall have an "as-is" bulk density of 40-50 pounds per cubic foot (lb/cf). In composts that have a moisture content of 40% to 60%, this equates to a bulk density range of 450-800 pounds per cubic yard (lb/cy) by dry weight.
  - Carbon to Nitrogen (C:N) Ratio: Composts shall have a C:N Ratio of less than 25:1.
  - pH: Composts shall have a pH of 6-8.
  - Cation Exchange Capacity (CEC): Composts shall have a CEC that exceeds 50 milliequivalents (meq) per 100 grams of dry weight.
  - Foreign Material Content: Composts shall contain less than 0.5% foreign materials (e.g., glass, plastic), by weight.
  - Pesticide Content: Composts shall be pesticide free.
- The use of biosolids (except Class A biosolids) and composted manure to amend soil is prohibited.
- Composts used to amend existing soils should be provided by a member of the U.S. Composting Seal of Testing Assurance program. Additional information on the Seal of Testing Assurance program is available on the following website: http://www.compostingcouncil.org.

Landscaping:

- Vegetation typically planted on restored pervious areas includes turf, shrubs, trees, and other herbaceous vegetation. Although managed turf is commonly used, trees, shrubs, and/or other native vegetation is encouraged to help establish mature, native plant communities (e.g., forests) in restored areas.
- Methods used to establish vegetative cover within a restored pervious area shall achieve at least 75% vegetative cover one year after installation. Bare soil is prohibited.
- To help prevent soil erosion and sediment loss, landscaping shall be installed immediately after the soil restoration process is complete. Temporary irrigation may be needed to quickly establish vegetative cover on a restored pervious area.

5.4.7 Retrofits

Above: Rooftops on existing buildings can provide an opportunity for a storm water retrofit, such as a green roof, and an additional amenity for building occupants. *(Source: EnvironmentalLeader.com)*

Description:

A storm water retrofit is a practice designed and implemented on an existing development to address storm water issues that arise after construction is completed. Such issues occur for sites that are developed prior to storm water requirements, have untreated or inadequately treated storm water, or where the owner desires additional storm water control.

Benefits:

Storm water retrofits can have many benefits, including:

- Addressing storm water or flooding concerns that became apparent after initial site development;
- Providing an opportunity to break up impervious surface with greenspace; and
- Creating an educational feature or pilot project.

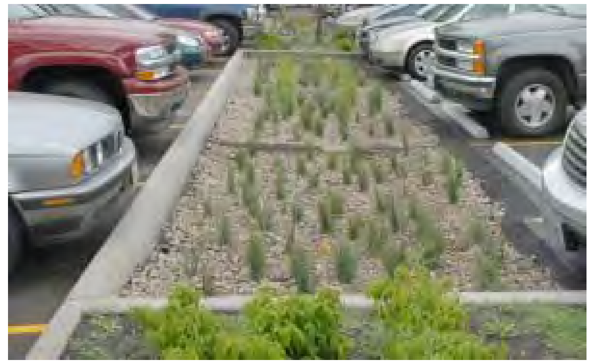
Additional guidance is available from the *Alabama LID Handbook*, in the following chapters.

- **Chapter 5: Constructed Stormwater Wetlands**
- **Chapter 6: Permeable Pavement**
- **Chapter 7: Grassed Swales, Infiltration Swales, and Wet Swales**
- **Chapter 10: Green Roofs**
- **Chapter 12: Rain Gardens**
- **Chapter 13: Curb Cuts**

Right: Before and after pictures for a street tree retrofit project. With proper installation, street trees can provide substantial storm water benefits, even in urban settings.

Planning and Physical Feasibility:

A retrofit project can incorporate a GIP into an already developed site to help with a flooding problem, manage a pollutant, or reduce storm water runoff. Examples are listed below. Requirements and specifications for each GIP are provided in Chapter 6.



- Sediment basins on construction sites can be cleaned out and converted to storm water wetlands.
- Transportation projects can include bioretention areas, permeable pavement, and other GIPs.
- Concrete or asphalt parking lots, patios, and walkways can be replaced with permeable pavement.
- Some rooftops can be converted to green roofs with rooftop garden amenities.
- Curb cuts can route storm water to a landscaped area or a GIP.
- Parking lot islands can be converted to bioretention areas.

Top: Parking lot retrofit with a vegetated filter strip. *(Source: Chesapeake Stormwater Network)*

Middle: Bioretention bump-out used for street calming on 39th Street South in Birmingham, AL.

Bottom: A complete street was designed for the reconstruction of Bagby Street in Houston TX. The street includes numerous features for storm water management. *(Credit: Design Workshop)*

5.4.8 Complete Streets

Above: Complete street in Edmonston, MD where, through the help of grants and EPA funds, the community turned a derelict street into a thriving neighborhood asset. *(Credit: Eastern Shore Land Conservancy)*

Description:

The objective of "complete streets" is to create roadways and related infrastructure that provide safe travel for all street users. The design process takes into account parking, vehicle traffic, pedestrian/bicycle traffic, public transit, storm water management, people with disabilities, and other community needs.

Benefits:

The benefits of complete streets include:

- Creating a community asset and attracting people to the area;
- Providing some greenspace or creating areas for storm water managements;
- Providing attractive scenery for a development or streetscape;
- Increasing safety, accessibility, opportunities for fitness for the community; and
- Improving the value and livability of nearby properties.

Also refer to the following chapters in the *Alabama LID Handbook* for additional information.

- **Chapter 2: Site Selection**
- **Chapter 11: Riparian Buffers**

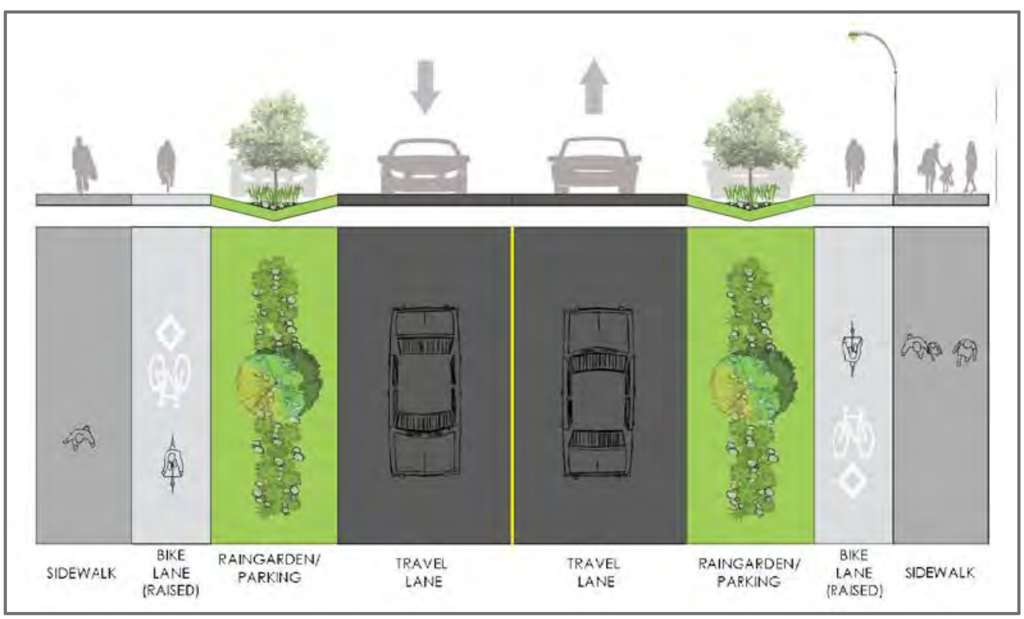
Above: Complete street view. Numerous municipalities across the United States are allowing the use of complete street concepts and designs in their communities. *(Source: Tri-County Regional Planning Commission, Harrisburg, PA)*

Planning and Physical Feasibility:

According to the National Complete Streets Coalition, typical elements that make up a complete street include sidewalks, bicycle lanes (or wide, paved shoulders), shared-use paths, designated bus lanes, safe and accessible transit stops, and frequent and safe crossings for pedestrians, including median islands, accessible pedestrian signals, and curb extensions. GIPs are often incorporated to manage storm water, increase greenspace, and urban habitat. Complete streets can be used for greenway connections (see Section 5.4.9).

Birmingham's Department of Planning, Engineering, and Permits supports and encourages the implementation of complete street designs. Further, the City is working to allow more complete streets options to ease the path toward design acceptance and permitting. Some steps to designing complete streets include:

- ❖ Consider the availability and accessibility of pedestrian access points to businesses, roadways, and walkways. This should include navigation by bicycle, wheelchair, and on foot.
- ❖ Examine vehicle, pedestrian, bicycle, and transit circulation for all projects with the goals of reducing congestion and reducing parking needs.
- ❖ Consider opportunities to use vegetated curbs, right-of-way bump outs, landscape islands, and GIPs along streets and parking areas.
- ❖ Look for opportunities to add complete street elements to projects. For example:
  - o A new pedestrian trail can be added along a new water quality swale
  - o A new bike lane can be added to a road re-surfacing project
  - o Curb cuts can be added to new landscaping islands
  - o Bicycle racks can be added to parking lot rehabilitations



Upper Right: The Cultural Trail in Indianapolis, IN featuring pedestrian and bicycle lanes, planters, and urban bioretention.

Lower Right: A typical Complete Street profile (top) and plan (bottom) views incorporating vehicular, bicycle, and pedestrian traffic, and areas for parking, greenspace, and storm water management. *(Source: Green Streets for Canada)*

5.4.9 Greenway Connections

Above: The multi-use trail in Birmingham's Railroad Park is an example of a park/greenway connection between downtown areas.

Description:

Greenway connections link various parts of the City with pedestrian paths, bicycle trails, and multi-use trails along linear vegetated routes. Greenways encourage fitness and recreation while also providing corridors for vegetation and wildlife. When greenway connections are incorporated, the design process should consider connectivity within the community, pedestrian/bicycle traffic, public transit, people with disabilities, and other community needs.

Benefits:

The benefits of greenway connections include:

- Creating a community asset and attracting people to the area;
- Providing greenspace or storm water management areas;
- Providing attractive scenery for a development or streetscape;
- Increasing safety, accessibility, opportunities for fitness for the community; and
- Obtain Leadership in Environmental and Energy Design (LEED) Points.

.

Also refer to the following chapter in the *Alabama LID Handbook* for additional information.

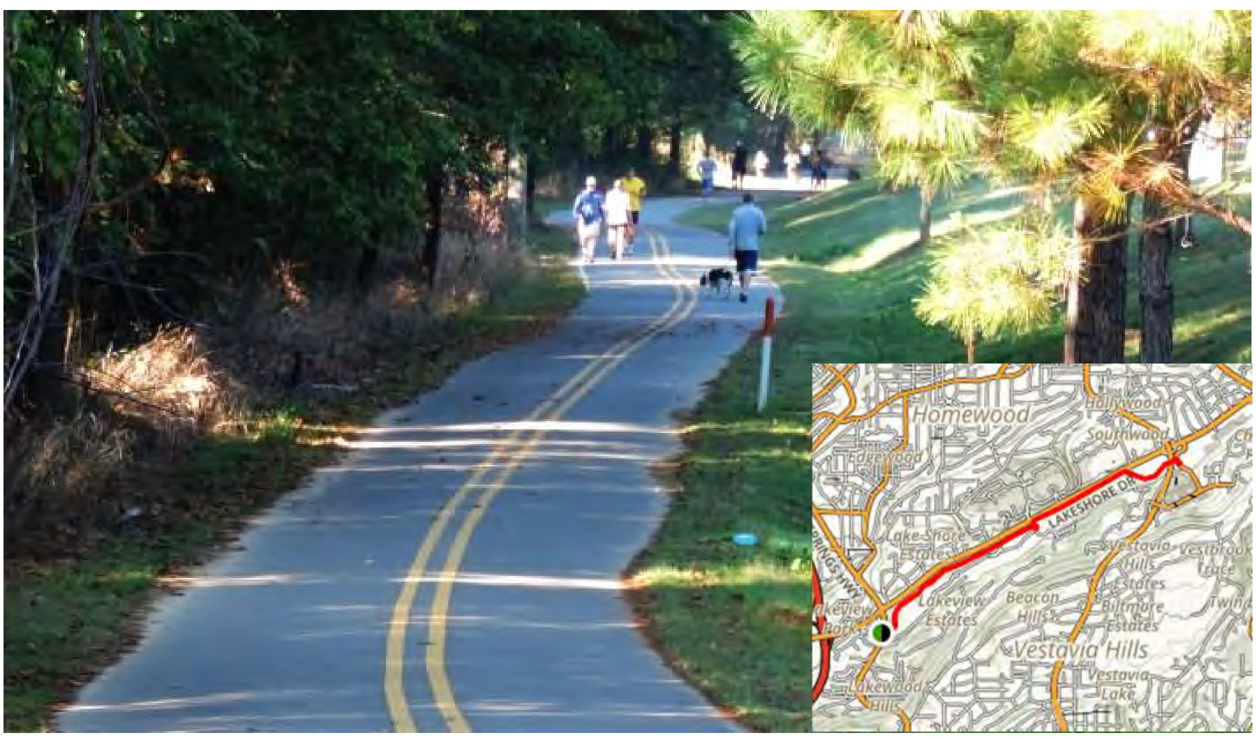
- **Chapter 3: Low Impact Development and Community Planning**

Planning and Physical Feasibility:

Through the *City of Birmingham Comprehensive Plan*, community framework plans, land development regulations, and various public projects, Birmingham is working to achieve its goal of providing recreational opportunities within a ten-minute walk of every resident. Having safe, connected pedestrian pathways is fundamental to this goal. Land developers, both public and private, can further the greenway connectivity throughout the City by considering greenways and potential connectivity in all projects. Some steps to help create greenway connections include the following measures.

- ❖ Become familiar with the Red Rock Ridge & Valley Trail System Plan, which involves creating and connecting six primary greenways and trails along the Birmingham area's waterways, including Shades Creek, Five-Mile Creek, Turkey Creek, Valley Creek, and the Cahaba River. Nearly 750-miles of greenway trails are envisioned (RedRockTrail.org).
- ❖ Consider if the project is connected to other complementary properties or projects or to a park, greenway, or other public property and work with the Department of Planning, Engineering, and Permits to find ways to connect properties.
- ❖ Work with the Department of Planning, Engineering, and Permits to remove obstacles that disconnect residents from greenspace and promote connectivity to these resources.
- ❖ Greenways don't have to involve park-like settings. Look for connections via pedestrian paths, bicycle trails, and multi-use trails along streets and parking areas (see figure to the right).
- ❖ Examine vehicle, pedestrian, bicycle, and transit circulation for all projects with the goals of reducing congestion and reducing parking needs.

- ❖ Look for opportunities to enhance greenway connections near development projects. For example:
  - o Curb cuts can be added to landscaped islands.
  - o A pedestrian trail can be added along a water quality swale.
  - o A new bike lane can be added to a road re-surfacing project.
  - o Bicycle racks can be added to parking lot rehabilitations.



Above: The Homewood Shades Creek Greenway (also called Lakeshore Trail) is a three-mile-long multi-use trail meandering through floodplain forest along the banks of Shades Creek. The paved trail is frequented by joggers, bikers, and walkers during most daylight hours of the year and provides a chance to explore floodplain habitats of one of the most important streams in the Birmingham metropolitan area. The greenway is connected to Jemison Park and the Homewood Forest Preserve and will be eventually connected with Birmingham. *(Source: trekbirmingham.com)*

5.4.10 Pocket Parks

Above: Example of a pocket park on an urban street.

INCENTIVES

Storm water management elements in pocket parks may receive storm water from disconnected downspouts (see Chapter 6, Section 6.6).

Small-scale GIPs, such as bioretention (see Chapter 6, Section 6.3), urban bioretention (see Chapter 6, Section 6.4), and permeable pavement (see Chapter 6 Section 6.11) can be incorporated into the design of pocket parks.

Green space used in pocket parks generate very little runoff and can ease the path to compliance with storm water performance standards.

Description:

Pocket parks are small parks, with typically less than two acres of greenspace, in urban areas. They often incorporate community enrichment, fitness, or opportunities to interact with nature. They also feature storm water management elements and are a good opportunity for public education. Because of their size and versatility, there are many opportunities to provide green space on vacant lots, within existing right-of-way, or adjacent to development sites.

Benefits:

The benefits of pocket parks include:

- Creating a community asset and attracting people to the area for economic development;
- Can provide an opportunity to break up impervious surface with greenspace;
- Providing storm water management benefits; and
- Providing attractive scenery for a development or streetscape.

Also refer to the following chapter in the *Alabama LID Handbook* for additional information.

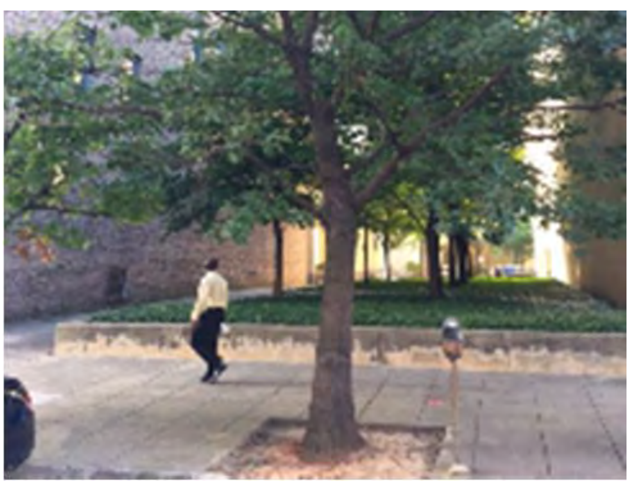
- **Chapter 3: Low Impact Development and Community Planning**

Above: Jemison Flats Pocket Park in Birmingham, AL. *(Courtesy: Macknally Land Design)*

Planning and Physical Feasibility

Pocket parks are most often created to provide gathering places for the community and to break up the urban landscape. Pocket parks can be a way to preserve urban trees or small landscaped areas and provide shade, evapotranspiration, and greenspace in an urban area. LID storm water elements, such as infiltration areas, tree boxes, or small cisterns can also be incorporated. If more tangible storm water benefits are desired, urban bioretention should be considered. Proper planning and implementation can make pocket parks an asset to the community. Some steps include:

- Become familiar with the Birmingham Comprehensive Plan, community frame work plans, parks plans, and the Red Rock Ridge & Valley Trail System Plan. These resources can lead to opportunities for partnerships in the creation of pocket parks.
- Consider where vacant lots or other empty space could be used for a pocket park and what areas would get the most use by the community.
- Identify partners for the project, such as community members, landscape architects, and other professions, service groups, and city representatives. Design and maintenance should be discussed with partners to garner support.
- Consider the uses of the pocket park and needs of the neighborhood. Pocket parks can be used for fitness, recreation, small events, gatherings, children's play areas, art displays, and other uses.
- Pocket parks often incorporate interesting focal points to attract people, such as: art, water features, landscaping, sun shades, interesting textures, varying platform levels, and use of vertical space.
- Help create connections between greenspace with sidewalks, nature trails, bike trails, and other pathways.
- A long-term management plan shall be developed for all landscaped areas and areas used for storm water management. The plan shall clearly specify how the area will be maintained over time. Because pocket parks are a community asset, often community groups or residents can participate in maintenance as volunteer activities.



Above left: Pocket park opportunity in Birmingham, AL. This mature, downtown green space could be redesigned to make a great urban pocket park. Exchange the raised planters for urban bioretention areas, add seating, and perhaps a water element or decorative art. *(Credit: Bhamarchitect's Blog)* **Above right:** Pocket Park in Manhattan NY. *(Credit: John Glines)* **Lower right:** Pocket park design for Matthews NC, near the town's Four Mile Creek Greenway. *(Courtesy: Town of Matthews)*

Chapter 6. GIP and BMP Design Specifications

A variety of green infrastructure choices allow designers the flexibility to enhance the vitality of the City for generations to come.

Green Infrastructure Selection Process

Runoff Reduction and Pollutant Removal Capability

The City makes every effort to consistently meet clean water standards.

The City is committed to practical, constructible, and maintainable solutions.

Green Infrastructure Design Specification Sheets

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GIP/BMP Design Specification Sheets

6.1 Introduction

Structural storm water practices are engineered facilities that are intended to reduce storm water pollutants and/or mitigate the effects of increased peak discharge, volume, and velocity resulting from land development. This chapter provides detailed descriptions and design specifications for the structural practices that are acceptable for use in Birmingham to address the storm water performance standards established in Chapter 3. In other words, the use of one or more of the structural practices described in this chapter in land development design will:

- Provide storm water quality protection by reducing the runoff reduction volume coefficient (Rv) and treating the water quality volume (WQv);
- Provide small storm extended detention by controlling the extended detention volume (EDv) for the 1-year design storm event;
- Provide flood protection by controlling the peak discharge for the 2-year, 10-year, and 25-year design storm events; and
- Safely pass the peak discharge for the 100-year design storm event.

The *City of Birmingham Post Construction Storm Water Ordinance* requires that all the structural practices used for a land development be designed, constructed, and maintained in accordance with the specifications presented in this manual.

The structural storm water practices included in this chapter can be categorized into two different types: green infrastructure practices (GIPs) and the more traditional best management practices (BMPs). Their differences are addressed in the next section. The design specifications for the GIPs and BMPs in this chapter facilitates their integration into many common urban and suburban land uses and on both public and private property. Practices 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 control.

Section 6.2 that follows provides general information on GIP and BMP selection. Detailed design specifications for all GIPs and BMPs are provided in Sections 6.3 through 6.20.

6.2 GIP/BMP Overview and Selection

6.2.1 Green Infrastructure Practices (GIPs)

GIPs are engineered storm water management facilities designed to reduce and/or treat storm water runoff, which mitigate the effects of increased storm water runoff peak rate, volume, and velocity due to urbanization. They are intended to mimic the natural hydrologic condition and allow storm water to infiltrate into the ground, evapotranspire, or be captured for reuse. Typical GIPs include: downspout disconnection, sheet flow, infiltration practices, permeable pavement, rain barrels/cisterns, bioretention, green roofs, and assorted other practices.

Generally speaking, as a storm water practice group, GIPs will typically provide storm water quality protection to a much higher degree than the more traditional storm water BMPs such as detention ponds and engineered wetlands. This is because GIPs tend to target volume, and therefore, pollutant reduction. Stated otherwise, the storm water volume that is infiltrated, evapotranspired, or stored and reused by a GIP is entirely "removed" from the storm drainage system and, therefore, does not discharge pollutants offsite. A tradeoff for this high degree of pollutant removal, however, is that GIPs are often less effective as flood protection practices because they typically do not manage large storm events.

6.2.2 Best Management Practices (BMPs)

Storm water BMPs are engineered practices that manage storm water using a variety of mechanisms. For storm water quality protection, BMPs generally reduce pollutants (total suspended solids, or TSS, in Birmingham) via filtration, settling, or mechanical means such as swirling (centrifugal force), floatation, or baffling. For flood protection, these BMPs store storm water, either temporarily (detention) or permanently (retention). All BMPs can provide some degree of TSS removal and nearly all can provide flood protection.

6.2.3 Storm Water Practice Differences and Usage

In contrast to GIPs, storm water BMPs are generally less effective than GIPs in reducing storm water TSS because they operate by removing pollutants before storm water discharge, rather than removing storm water volume. The latter stated mechanism is generally preferred in Birmingham because storm water volume reductions can lead to a reduced need for storm water management, both onsite and offsite. In other words, less storm water requires smaller drainage systems and less systems to operate and maintain. To encourage the use of GIPs, Birmingham's storm water quality performance standard established in Chapter 3 requires that site designers should *consider* GIPs as their first storm water practice option. The use of GIPs to manage storm water is not required. Rather, the consideration of GIPs is required for all land developments. This consideration is documented in the storm water management plan. The City does recognize that GIPs will not be feasible for use on all land developments; therefore, site designers can opt to use BMPs to achieve the required standard. Policies pertaining to the consideration and usage of GIPs and BMPs are provided in Chapter 3.

In practice, site designers will often use combinations of small, localized GIPs and BMPs in a "treatment train" to satisfy storm water management requirements. Guidance on design calculations for GIPs and BMPs used alone or in combination are provided in Chapter 4.

6.2.4 Storm Water Practice Selection

Table 6-1 lists the GIPs and BMPs deemed acceptable for use in Birmingham. A detailed discussion of each of the practice, as well as design criteria and procedures for each, can be found in Sections 6.3 through 6.20.

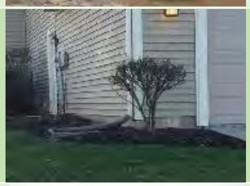
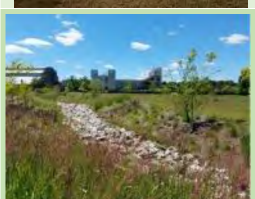
6.2.5 Runoff Reduction & Pollutant Removal Capability

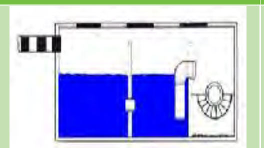
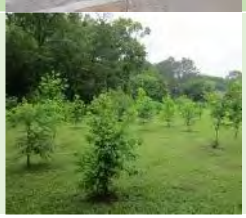
From a compliance calculation perspective, GIPs and BMPs provide volume reduction and TSS removal, respectively. The relative capabilities vary among the different types of practices. These capabilities for a given GIP/BMP are based on several factors including the physical, chemical, and/or biological processes that take place and the practice's design and size. In addition, TSS removal efficiencies for the same BMP type and facility design can vary depending on the tributary land use and area, incoming TSS concentrations, rainfall pattern, time of year, maintenance frequency, and numerous other factors.

To assist designers in evaluating the various GIP/BMP options for their land development, **Table 6-2** provides an overview of runoff reduction (RR) credits, % TSS removal, site applicability, and maintenance and cost considerations. RR credits are based on continuous simulation modeling of GIPs in Birmingham for rainfall and soil conditions. TSS removal values are conservative average pollutant reduction percentages derived from sampling data, modeling, and professional judgment. Practices may be capable of exceeding these performances; however, the values are minimum reasonable values that can be assumed to be achieved when the practice is sized, designed, constructed, and maintained in accordance with recommended specifications in this manual.

Additional information on GIPs and BMPs capabilities is available from the National Pollutant Removal Performance Database (3rd Edition) available at www.cwp.org and the National Stormwater Integrated Management Practices (GIP) Database at **www.bmpdatabase.org**.

Table 6-1. GIPs and BMPs for Use in Birmingham

GIP/BMP		Description
Bioretention (GIP)		Bioretention areas are shallow storm water basins or landscaped areas that utilize engineered soils and vegetation to capture and treat storm water runoff. Bioretention areas may be designed with an underdrain that returns runoff to the conveyance system or designed without an underdrain to exfiltrate runoff into the soil.
Cistern (GIP)		Cisterns are common storm water management practice used to catch rainfall and store it for later use. Typically, gutters and downspout systems are used to collect the water from roof tops and direct it to a storage tank. Rainwater harvesting systems can be either above or below the ground. Once captured in the storage tank, the water may be used for non-potable indoor (requires treatment) and outdoor uses.
Downspout Disconnects (GIP)		A downspout disconnect spreads rooftop runoff from individual downspouts across lawns, vegetated areas, and other pervious areas, where the runoff is slowed, filtered, and can infiltrate into the native soils.
Dry Detention Pond and Dry Extended Detention Pond (BMP)		Dry detention ponds are surface facilities intended to provide temporary storage of storm water runoff to reduce downstream water quantity impacts. Dry extended detention (ED) ponds are surface facilities intended to provide temporary storage of storm water runoff to reduce downstream water quantity impacts.
Dry Water Quality Swale/ Enhanced Swale (GIP)		Dry water quality swales and enhanced swales are vegetated open channels that are designed and constructed to capture and treat storm water runoff within dry or wet cells formed by check dams or other structures.
Grass Channel/Open Channel (BMP)		Grass channels and open channels are vegetated open channels that provide “biofiltering” of storm water runoff as it flows across the grass surface.

GIP/BMP		Description
Gravity (Oil-Grit) Separator (BMP)		Gravity oil-grit separators are hydrodynamic controls that use the movement of storm water runoff through a specially-designed structure to remove target pollutants. They are typically used on smaller, impervious, commercial sites and urban hotspots.
Green Roof (GIP)		Green roofs represent an alternative to traditional impervious roof surfaces and typically consist of underlying water proofing, drainage systems, and an engineered planting media. Storm water runoff is captured and temporarily stored in the engineered planting media, where it is subjected to evaporation and transpiration before being conveyed back into the storm drain system. There are two different types of green roof systems. Intensive green roofs have a thick layer of soil, can support a diverse plant community, and may include trees. Extensive green roofs have a much thinner layer of soil that is comprised primarily of drought tolerant vegetation.
Infiltration Trench (GIP)		An infiltration trench is a shallow excavation, typically filled with stone or an engineered soil mix, which is designed to temporarily hold storm water runoff until it infiltrates into the surrounding soils. Infiltration practices can reduce storm water quantity, recharge the groundwater, and reduce pollutant loads.
Manufactured Treatment Device (BMP)		Manufactured Treatment Devices (MTDs) are manufactured structural control systems available from commercial vendors that are designed to treat storm water runoff and/or provide water quantity control. Proprietary systems often can be used on small sites and in space-limited areas.
Permeable Pavement (GIP)		Permeable pavement is pavers or pervious concrete or asphalt with void areas that are generally filled with pervious materials. They are designed with an underlying stone reservoir to temporarily store surface runoff before it infiltrates into the subsoil and/or flows out through an underdrain system.
Reforestation (GIP)		Reforestation is a process of planting trees, shrubs, and other native vegetation in disturbed pervious areas to restore the area to pre-development or better conditions. The process can be used to establish mature native plant communities, such as forests, in pervious areas that have been disturbed by clearing, grading, and other land disturbing activities.

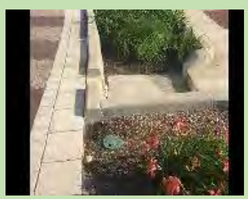
GIP/BMP		Description
Sand Filters (BMP)		Sand filters are multi-chamber structures designed to treat storm water runoff through filtration, using a sand bed as its primary filter media. Filtered runoff may be returned to the conveyance system through an underdrain system or allowed to partially exfiltrate into the soil.
Sheet Flow (GIP)		Sheet flow is the practice of disconnecting impervious areas and routing runoff over a level spreader so that it flows over adjacent vegetated areas. This slows runoff velocities, promotes infiltration, and allows sediment and attached pollutants to settle and/or be filtered by the vegetation.
Storm Water Wetland/Gravel Wetland (BMP)		Storm water wetlands are constructed wetland systems used for storm water management. Storm water wetlands consist of a combination of shallow marsh areas, open water, and semi-wet areas above the permanent water surface. As storm water runoff flows through a wetland, it is treated, primarily through gravitational settling and biological uptake. A submerged gravel wetland has one or more treatment cells that are filled with crushed rock or gravel and is designed to allow storm water to flow subsurface through the root zone of the constructed wetland.
Underground Detention (BMP)		Underground detention tanks and vaults provide temporary storage of storm water runoff for space-limited areas where there is not adequate land for a dry detention basin or multi-purpose detention area.
Urban Bioretention (GIP)		Urban bioretention is similar to traditional bioretention practices, except that the bioretention is fit into concrete-sided containers within urban landscapes, such as planter boxes or tree planters. Captured runoff is treated by filtration through an engineered soil medium and is then either infiltrated into the subsoil or exfiltrated through an underdrain.

Table 6-2. Runoff Reduction Credit and Pollutant Removal Capabilities for GIPs and BMPs

	Runoff Reduction	Storm Water Management & Treatment							Site Applicability						Cost Considerations	
GIP or BMP	Runoff Reduction Credit (RR Credit)	WQ_v / TSS	CP_v	Q_{p25} / Q_f	Total Phosphorus	Total Nitrogen	Fecal Coliform	Metals	GIP	Drainage Area (ac)	Space Req'd (% of imperv. Drainage Area)	Max Site Slope	Minimum Head (Elevation Difference)	Depth to Water Table	Construction Cost	Maintenance Burden
Bioretention Areas [1,2,3]	56 Level 1/ 78 Level 2	85%	❖	❖	80%	60%	90%	95%	Yes	0.1-2.5	3-6%	5%	3 ft	2 ft	Low	Med
Downspout Disconnects [4]	Yes	80%	X	X	25%	25%	N/A**	40%	Yes	1,000 ft^2	Min. length of flow path 15'	6%	N/A	No restrictions	Low	Low
Dry Detention Pond and Dry Extended Detention Pond[3]	No	60%	X	✓	10%	30%	N/A**	50%	No	10 min	2-3%	15%	6-10 ft	Can't intersect	Low	Med
Extended Detention Basin/Storm Water Wet Pond [4]	7 Level 1/ 0 Level 2	60%	✓	✓	10%	30%	N/A**	50%	No	10 min	2-3%	15%	6-10 ft	3 ft or liner	Low	Med
Dry Water Quality Swale/Enhanced Swale [5]	32 Level 1/ 54 Level 2	80%	❖	X	50%	50%	X	40%	Yes	2.5 max	3-10%	4%	3 ft	2 ft	Low	Low
Grass Channel/Open Channel [5]	0-18 Level 1/ 6-25 Level 2	50%	❖	X	25%	20%	X	30%	Yes	5 max	10%	4%	3 ft	3 ft	Low	Low
Gravity (Oil-Grit) Separator [4]	No	40%	X	X	5%	5%	N/A	N/A	No	5 max	N/A	6%	4 ft	2 ft	Low	High
Green Roof [4]	77 Level 1/ 88 Level 2	80%	❖	❖	50%	50%	N/A**	N/A**	Yes	N/A	No restrictions	25%	N/A	N/A	High	Med
Infiltration Trench [6]	43 Level 1/ 89 Level 2	100%	❖	❖	100%	100%	100%	100%	Yes	5 max	3-6%	Varies	Varies t	2 ft	Med	Med
Permeable Pavement [4]	38 Level 1/ 72 Level 2	80%	❖	❖	50%	50%	N/A**	60%	Yes	N/A	No restrictions	6%	2-4 ft	2 ft	High	High
Manufactured Treatment Device [4]	No	Varies	❖	❖	Varies	Varies	Varies	Varies	No	Varies	Varies	Varies	Varies	Varies	Varies	Varies
Cistern [4]	Design dependent	Varies	❖	❖	Varies	Varies	Varies	Varies	Yes	No restrictions	Varies	No restrictions	N/A	N/A	Low	Med
Sand Filters [5]	No	80%	❖	X	50%	25%	40%	50%	Yes	2 max surface,10 max perimeter	2-3%	6%	6 ft surface, 2 ft perimeter	2 ft	Low	High
Reforestation[4]	Varies**	Varies **	❖**	❖**	Varies **	Varies **	Varies **	Varies**	Yes	N/A	5,000 ft^2 Min.	No restrictions	N/A	No restrictions	Low	Low
Sheet Flow	44 Level 1/ 50 Level 2	Varies	❖	❖	Varies	Varies	Varies	Varies	Yes	N/A	Varies	6%	N/A	No restrictions	Low	Low
Storm Water Wetland/ Gravel Wetlands [4,7]	No	80%	X	✓	50%	20%	70%	50%	Yes	5 max	2-3%	4%	varies	2ft (if hot spot)	Low	Med
Underground Detention [4]	No	0%	✓	✓	0%	0%	0%	0%	No	25 max	N/A	15%	N/A	N/A	Med	Low
Urban Bioretention	56 Level 1/ not approved for Level 2	85%	❖	❖	80%	60%	90%	95%	Yes	0.1-2.5	3-6%	N/A	3 ft	2 ft	Low	Med

✓ - GIP can meet the storm water management or treatment requirement

❖ - GIP may meet the storm water management or treatment requirement depending on size, configuration, and site constraints

X - GIP may contribute but is not likely to fully meet the storm water management or treatment requirement

* - Minimum drainage area of ten acres is required to maintain the permanent pool (unless groundwater is present).

**- Helps restore pre-development hydrology, which implicitly reduces post-construction storm water runoff rates, volumes and pollutant loads. Refer to Chapter 4 for incentives.

*** - Runoff reduction percentages are listed in Chapter 6.

Pollutant Removal References:

1: Bioretention - Watershed Benefits. Low Impact Development Urban Design Tools. 04 April 2014.
2: Bioretention Performance, Design, Construction, and Maintenance. North Carolina Cooperative Extension Service. Hunt, William. 2006.
3: North Carolina Department of Environment and Natural Resources Stormwater Integrated Management Practices Manual. 2007.
4: Previous Coastal Stormwater Supplement to the Georgia Stormwater Management Manual, 2009.
5: Original Georgia Stormwater Management Manual, 2001.
6: Pollutant removal rates based on 100% infiltration with no underdrain.
7: The Next Generation of Stormwater Wetlands. EPA Wetlands and Watersheds Article Series (2008) Center for Watershed Protection.

6.2.6 GIP/BMP Design Specification Sheets

Specifications for each GIP and BMP deemed acceptable for use in Birmingham are provided in the sections that follow, arranged by practice in practice-specific design sheets.

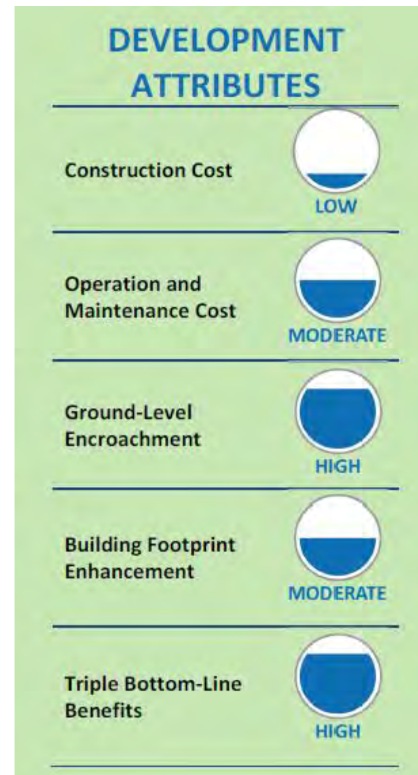
The first page of each GIP/BMP design specification sheet is set up to be a concise overview of the practice and provides the **description, variations, key advantages, key limitations,** and **performance standards** for the specific practice. Icons are provided at the top right corner to indicate the "type" of practice and the pollutant removal capabilities. **Figure 6-1** indicates of the "type" of practice as they are identified in the design specification sheets.

Figure 6-1. Storm Water Practice Types

In addition, each GIP or BMP is provided a rating (low, medium, or high) in the following **development attribute** categories as an initial step in evaluating the applicability of the GIP. See **Figure 6-2** and the explanation below.

- **Construction Costs**: The estimated implementation costs associated with the construction of the GIP or BMP per acre of directly connected impervious area treated.
- **Operation and Maintenance Costs**: The estimated annual costs associated with operation and maintenance activities for the GIP or BMP.
- **Ground-Level Encroachment**: Encroachment onto potential usable, open space on the ground-level surface of the site.
- **Building Footprint Encroachment**: Encroachment onto site area that could otherwise be used for building footprint.
- **Triple Bottom Line**: The ability of the GIP or BMP to provide social, environmental, and economic benefits (land value, energy efficiency, etc.).

Figure 6-2. Storm Water Practice Attributes



After the first page, the remaining pages of each GIP/BMP specification sheet provides the following information:

General Application: The General Application Section provides an overview of the practice, variations of the practice, and various areas in a site development that the practice can be used in (parking lot islands, courtyards, right of ways, etc.). In addition, a rendering labeled with the basic components of the practice is provided in this section (as shown in **Figure 6-3**).

- **Planning and Physical Feasibility:** The Planning and Physical Feasibility Section provides information that should be determined early in the process to determine what type of specific constraints are on your site and what the specific suitability of the practice is on the development site. For each practice, a table as shown in Figure 6-3 is provided to easily reference and summarize the information.
- **Design Requirements:** The Design Requirements Section provides information to size the practice for compliance. It provides the design criteria, sizing equations, and specific runoff reduction credit values or % TSS removal values that can be obtained for the specific design. In addition, material specifications are provided in this section. Appendix F provides typical details for each practice that also contains material specifications and design requirements.
- **Construction, Protection, and Maintenance Requirements:** This section provides the guidelines and requirements for each practice. The design of all practices shall include consideration for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed for each practice and is described in this section. Per Section 450 Stormwater Management of the CRS Coordinator's Manual, various storm water practices that are maintained are eligible to receive credit points.

Figure 6-3. Example GIP Design Specification Graphic and Tables

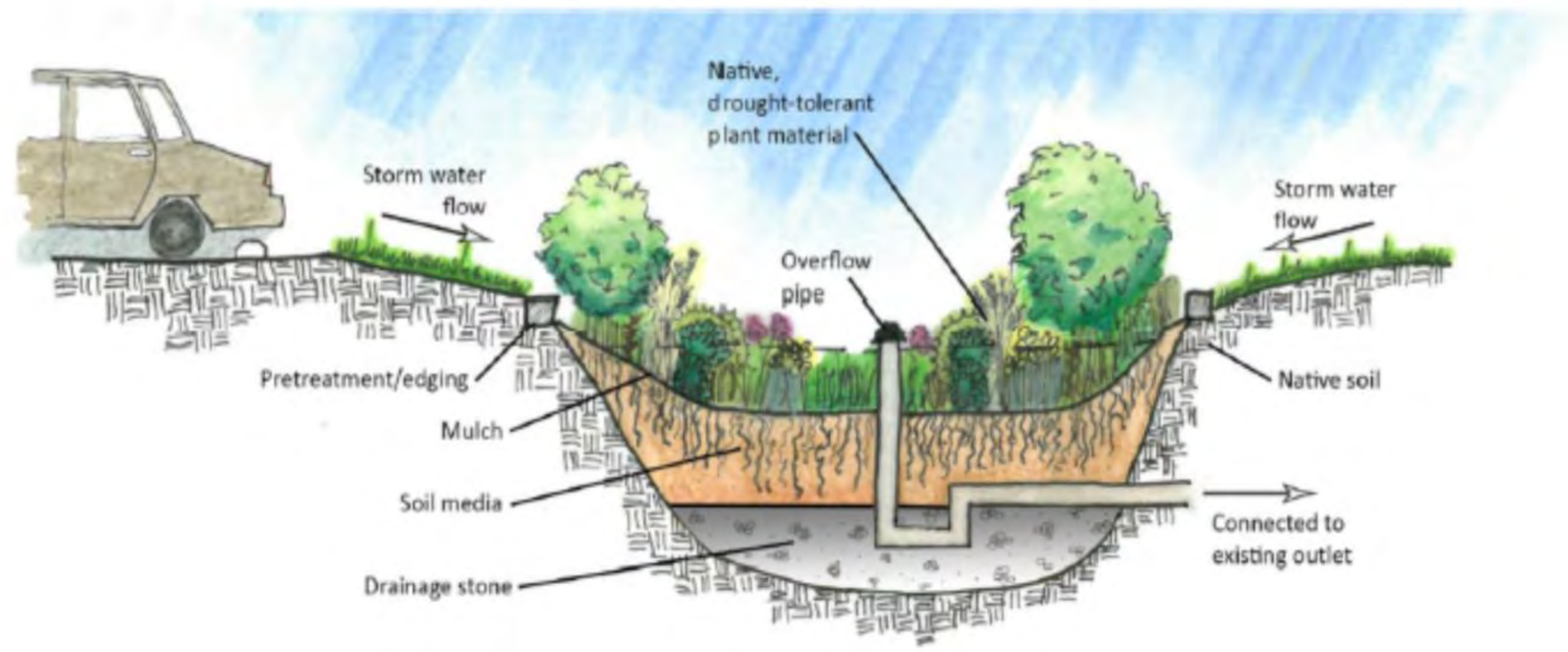


Table 6.3.1: Bioretention Constraints

Bed Depth	Contributing Drainage Area	Floodplains	Hotspot Land Uses	Hydraulic Head needed	Irrigation or Baseflow	Ponding Depth
Min 24" (Level 1) Min 36" (Level 2)	0.1-2.5 acres or adequate pre-treatment/treatment train	Not allowed	Underdrain required, refer to hotspot guidance	3' min. Linear, multi-cell systems may also be used.	Avoid access non-storm water run-on. Irrigate if necessary for survival	6-9"
Setbacks	**Site Topography Needed**	**Soils Requirement**	**Space Needed**	**Underdrain**	**Utility Requirement**	**Water Table Requirement**
Water supply wells require 100'. Septic systems require 50'.Impermeable barrier required close to structures/roadways.	Slope greater than 1% and less than 5%. Terracing or other inlet controls may be used to slow runoff velocities.	HSG C or D need an underdrain. Infiltration test required	3-10% of contributing drainage area	Shall be tied to ditch or conveyance system	Consider clearance for all utilities. Min. 5' from down-gradient wet utility lines. Double-cased Dry utility lines may cross under	2' of separation

Table 6.3.2. Bioretention Design Criteria

Level 1 Design (RR 56)	Level 2 Design (RR: 78)
Sizing-see sizing section below	**Sizing**-see sizing section below
Surface Area (sq. ft.) = (Tv – the volume reduced by an upstream GIP) / Storage Depth [1]	**Surface Area (sq. ft.)** = [(1.25)(Tv) – the volume reduced by an upstream GIP] /Storage Depth [1]
Recommended maximum contributing impervious drainage area = 2.5 acres	
Maximum Ponding Depth = 6 inches	
Filter Media Depth minimum = 24 inches; **recommended maximum** = 6 feet	**Filter Media Depth minimum** = 36 inches; **recommended maximum** = 6 feet
Media & Surface Cover = mixed onsite or supplied by vendor; the final composition shall be: Max 60% sand; less than 40% silt; 5% to 10% organic matter; and less than 20% clay by volume	
Sub-soil Testing: not needed if an underdrain is used; Min infiltration rate > 0.5 inch/hour in order to remove the underdrain requirement.	**Sub-soil Testing**: not needed if an underdrain is used; Min infiltration rate > 0.5 inch/hour in order to remove the underdrain requirement. Refer to **Appendix 6** for soil testing.
Underdrain = PVC or Corrugated HDPE with clean-outs ***OR***, none, if soil infiltration requirements are met	**Underdrain & Underground Storage Layer** = PVC or Corrugated HDPE with clean outs, and a minimum 12-inch stone sump below the invert; ***OR***, none, if soil infiltration requirements are

6.3 Bioretention

Figure 6.3.1. Bioretention Area at Railroad Park in Birmingham, AL

DEVELOPMENT ATTRIBUTES

Construction Cost	LOW
Operation and Maintenance Cost	MODERATE
Ground-Level Encroachment	HIGH
Building Footprint Enhancement	MODERATE
Triple Bottom-Line Benefits	HIGH

Description:

Bioretention cells are vegetated, shallow depressions used to promote absorption and infiltration of runoff. Captured runoff is treated by filtration through an engineered soil medium and is then either infiltrated into the subsoil or exfiltrated through an underdrain.

Variations:

Constructed without underdrain in soils with measured infiltration rates greater than 0.5 inches per hour and with an underdrain in less permeable soils.

Key Advantages:

- Flexible layout and easy to incorporate in landscaped areas
- Very effective at removing pollutants and reducing runoff volumes
- Generally, one of the more cost-effective storm water management options
- Relatively low maintenance activities costs
- Can contribute to better air quality and help reduce urban heat island impacts
- Can improve property values and site aesthetics through attractive landscaping
- Habitat creation

Key Limitations:

- May need to be combined with other GIPs to meet the Extreme Flood Protection requirement
- May have limited opportunities for implementation due to the amount of open space available at the site

PERFORMANCE STANDARD COMPLIANCE					
Water Quality			Stream Channel Protection	Overbank Flood Protection	Extreme Flood Protection
Treatment Volume		80% TSS Removal			
Level 1	Level 2				
56 RR Credit	78 RR Credit	✓	▶	▶	▶

✓ Suitable for this practice

▶ Provides partial benefits

6.3.1 General Application

Bioretention can be used where storm water can be conveyed to a surface area. Bioretention has been used at commercial, institutional, and residential sites in spaces that are traditionally pervious and landscaped. It should be noted that special care shall be taken to provide adequate pre-treatment for bioretention cells in space-constrained high traffic areas. Typical locations for bioretention include the following:

Figure 6.3.2. Bioretention – Before and After Parking Lot Island

Parking lot islands. The parking lot grading is designed for sheet flow towards linear landscaping areas and parking islands between rows of spaces. Curb-less pavement edges can be used to convey water into a depressed island landscaping area. Curb cuts can also be used for this purpose.

Parking lot edge. Small parking lots can be graded so that flows reach a curb-less pavement edge or curb cut before reaching catch basins or storm drain inlets.

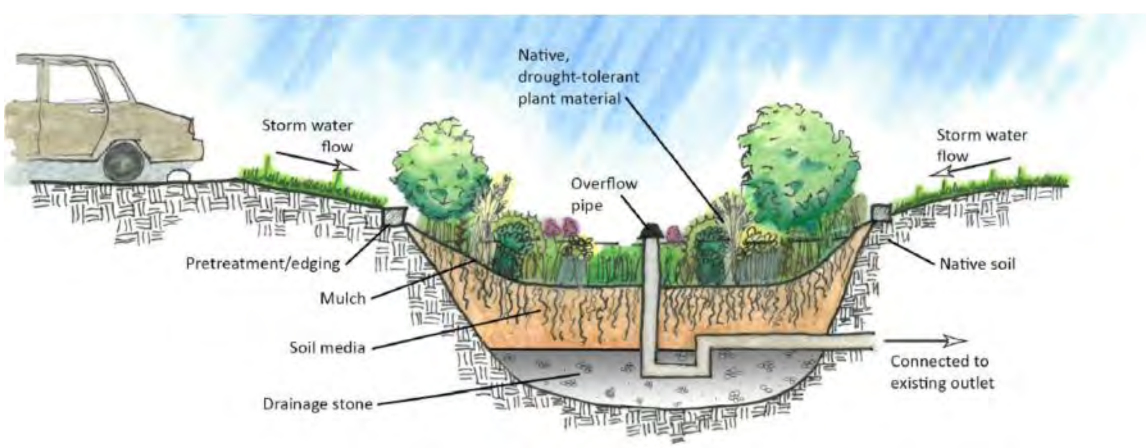
Right of Way or commercial setback. A linear configuration can be used to convey runoff in sheet flow from the roadway, or a grass channel or pipe may convey flows to the bioretention practice.

Courtyards. Runoff collected in a storm drain system or roof leaders can be directed to courtyards or other pervious areas on site where bioretention can be installed.

Unused pervious areas on a site. Storm flows can be redirected from a storm drain pipe to discharge into a bioretention area.

Dry Extended Detention (ED) basin. A bioretention cell can be located on an upper shelf of an extended detention basin, after the sediment forebay, in order to boost treatment.

Retrofitting. Numerous options are available to retrofit bioretention in the urban landscape. Some are described Chapter 6, Section 4: Urban Bioretention.



6.3.2 Planning and Physical Feasibility

Bioretention can be applied in most soils or topography since runoff simply percolates through an engineered soil bed and can be returned to the storm water system if the infiltration rate of the underlying soils is too low. The following criteria provided in **Table 6.3.1** shall be considered when evaluating the suitability of a bioretention area for a development site.

Table 6.3.1. Bioretention Constraints

Bed Depth	Contributing Drainage Area	Floodplains	Hotspot Land Uses	Hydraulic Head needed	Irrigation or Baseflow	Ponding Depth
Min 18" (Level 1) Min 36" (Level 2)	0.1-2.5 acres or adequate pre-treatment/treatment train.	Not allowed.	Underdrain and liner may be required, refer to Appendix D.	3' min. Linear, multi-cell systems may also be used.	Avoid access non-storm water run-on. Irrigate if necessary for survival.	6-9"
Setbacks	Site Topography Needed	Soils Requirement	Space Needed	Underdrain	Utility Requirement	Water Table Requirement
Water supply wells require 100'. Septic systems require 50'. Impermeable barrier required close to structures/roadways.	Slope greater than 1% and less than 5%. Terracing or other inlet controls may be used to slow runoff velocities.	HSG C or D need an underdrain. Infiltration test required.	3-10% of contributing drainage area.	Shall be tied to ditch or conveyance system.	Consider clearance for all utilities. Min. 5' from down-gradient wet utility lines. Double-cased Dry utility lines may cross under.	2' of separation.

The data listed below is necessary for the design of a bioretention area and shall be included with the development plan. See Appendix B for more information on required elements for the storm water management plan (SWMP).

- Existing and proposed site, topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Water surface elevation of nearby water systems as well as the depth to seasonally high groundwater.
- If no underdrain is proposed for the bioretention area, then infiltration testing of native soils at proposed elevation of bottom of bioretention area is required. See Appendix E for more information.
- If no underdrain is proposed, then the Infiltration Feasibility form provided in Appendix B shall be submitted with the SWMP.

6.3.3 Design Requirements

The major design goal for bioretention is to maximize runoff volume reduction and pollutant removal. To this end, designers may choose to go with the baseline design (Level 1 (**RR 56**)) or choose an enhanced design (Level 2 (**RR 78**)) that maximizes pollutant and runoff reduction. If soil conditions require an underdrain, bioretention areas can still qualify for the Level 2 design if they contain a stone storage layer beneath the invert of the underdrain. Design criteria for Level 1 and Level 2 Bioretention are summarized in **Table 6.3.2**. Typical details are located in Appendix F.

Table 6.3.2. Bioretention Design Criteria

Level 1 Design (RR 56)	Level 2 Design (RR: 78)
Sizing – See sizing section below	Sizing – See sizing section below
Surface Area (sq. ft.) = (Tv – the volume reduced by an upstream GIP) / Storage Depth [1]	Surface Area (sq. ft.) = [(1.25)(Tv) – the volume reduced by an upstream GIP] /Storage Depth [1]
Recommended maximum contributing impervious drainage area = 2.5 acres	
Maximum Ponding Depth = 6 inches	
Filter Media Depth minimum = 18 inches; recommended maximum = 6 feet	Filter Media Depth minimum = 36 inches; recommended maximum = 6 feet
Media & Surface Cover = mixed onsite or supplied by vendor; the final composition shall be: Max 60% sand; less than 40% silt; 5% to 10% organic matter; and less than 20% clay by volume.	
Sub-soil Testing: not needed if an underdrain is used; Min infiltration rate > 0.5 inch/hour to remove the underdrain requirement.	Sub-soil Testing: not needed if an underdrain is used; Min infiltration rate > 0.5 inch/hour to remove the underdrain requirement. Refer to Appendix E for soil testing.
Underdrain = Schedule 40 or SDR 35 smooth wall PVC pipewith clean-outs *OR*, none, if soil infiltration requirements are met.	Underdrain & Underground Storage Layer = Schedule 40 or SDR 35 smooth wall PVC pipewith clean outs, and a minimum 12-inch stone sump below the invert; *OR*, none, if soil infiltration requirements are met. Refer to Chapter 6, Section 2 for Common Components.
Inflow: sheet flow, curb cuts, trench drains, concentrated flow, or the equivalent	
Geometry Length of shortest flow path/Overall length = 0.3; *OR*, other design methods used to prevent short- circuiting; a one-cell design (not including the pre- treatment cell).	Geometry Length of shortest flow path/Overall length = 0.8; *OR*, other design methods used to prevent short-circuiting; a two-cell design (not including the pretreatment cell).
Pre-treatment: a pretreatment cell, grass filter strip, gravel diaphragm, gravel flow spreader, or another approved (manufactured) pre-treatment structure.	Pre-treatment: a pretreatment cell plus one of the following: a grass filter strip, gravel diaphragm, gravel flow spreader, or another approved (manufactured) pre-treatment structure.
Conveyance & Overflow (see below)	Conveyance & Overflow (see below)
Planting Plan: a planting template to include perennials, grasses, sedges or shrubs to achieve a surface area coverage[3] of at least 75% within 2 years by using the recommended spacing in Appendix C.	Planting Plan: a planting template to include perennials, grasses, hedges, and shrubs to achieve surface area coverage of at least 75% within 2 years and include trees planted at 1 tree/400 s.f. Refer to Appendix C for Planting Plans.
Suggested Building Setbacks [2]	
0 to 0.5 acres CDA = 10 feet if down-gradient from building or level; 50 feet if up-gradient. 0.5 to 2.5 acres CDA = 25 feet if down-gradient from building or level; 100 feet if up-gradient. (Refer to additional setback criteria)	
Long Term Maintenance Requirements (see below)	

1 Storage depth is the sum of the Void Ratio (Vr) of the soil media and gravel layers multiplied by their respective depths, plus the surface ponding depth. Refer to **Sizing of Bioretention Practices below**.

2 These are recommendations for simple building foundations. If an in-ground basement or other special conditions exist, the design shall be reviewed by a licensed engineer. Also, a special footing or drainage design may be used to justify a reduction of the setbacks noted above.

3 Surface area coverage in reference to planting is the percentage of vegetative cover in a planting area.

Sizing of Bioretention Practices

Storm Water Quality

Sizing of the surface area (SA) for bioretention practices is based on the computed Treatment Volume (T_v) of the contributing drainage area and the storage provided in the facility. The required surface area (in square feet) is computed as the Treatment Volume (in cubic feet) divided by the equivalent storage depth (in feet). The equivalent storage depth is computed as the depth of media, gravel, or surface ponding (in feet) multiplied by the accepted void ratio.

The accepted Void Ratios (V_r) are (see **Figure 6.3.3** below):

Bioretention Soil Media (See below)	$V_r = 0.40$
Gravel	$V_r = 0.40$
Surface Storage	$V_r = 1.0$

The equivalent storage depth for Level 1 with a 6-inch surface ponding depth is therefore computed as:

Equation 1: Bioretention Level 1 Design Storage Depth

$$\text{Equivalent Storage Depth} = D_E = V_r\ (D_1) + V_r\ (D_2) + \cdots$$

$$D_E = (2\ ft. \times 0.40) + (0.5 \times 1.0) = 1.30\ ft.$$

Where V_{r1} and D_1 are for the first layer, etc.

And the equivalent storage depth for Level 2 with 3 feet of media, a 6-inch surface ponding depth and a 12-inch gravel layer is computed as:

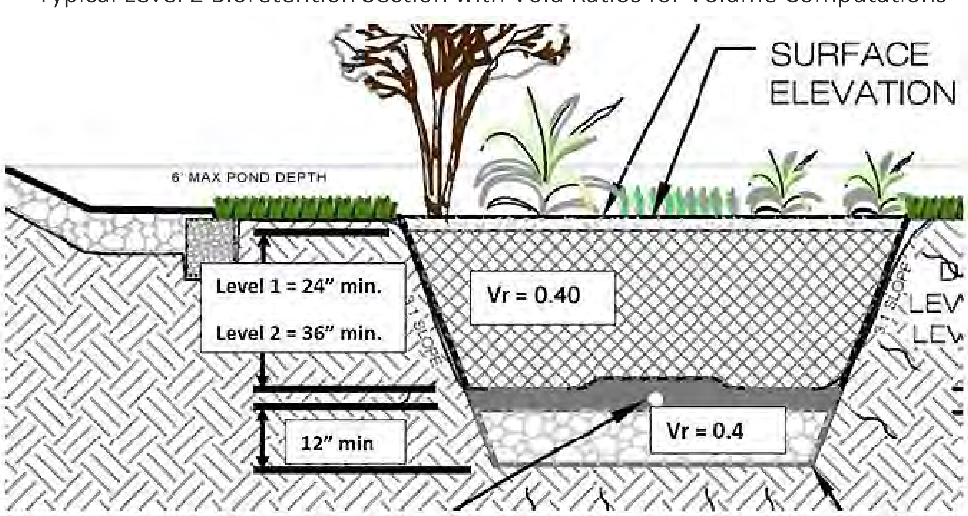
Equation 2: Bioretention Level 2 Design Storage Depth

$$\text{Equivalent Storage Depth} = D_E = V_r\ (D_1) + V_r\ (D_2) + \cdots$$

$$D_E = (3\ ft. \times 0.40) + (1\ ft. \times 0.40) + (0.5 \times 1.0) = 2.10\ ft$$

While this method is simplistic, simulation modeling has proven that it yields a total storage volume somewhat equivalent to 80% total average annual rainfall volume removal for infiltration rates from 0.5 in/hr through 1.2 in/hr. If the designer can show a measured subsurface infiltration rate above this value, size decreases may be requested on a case-by-case basis.

Figure 6.3.3. Typical Level 2 Bioretention Section with Void Ratios for Volume Computations



Therefore, the Level 1 Bioretention Surface Area (SA) is computed as:

Equation 3: Bioretention Level 1 Design Surface Area

$$SA\ (sq.\ ft.) = (T_v - \text{the volume reduced by an upstream GIP}) / D_E$$

And the Level 2 Bioretention Surface Area is computed as:

Equation 4: Bioretention Level 2 Design Surface Area

$$SA\ (sq.\ ft.) = [(1.25 * Tv) - \text{the volume reduced by an upstream GIP}] / D_E$$

Where:

SA = Minimum surface area of bioretention filter (sq. ft.)

D_E = *Equivalent Storage Depth (ft.)*

T_v = Treatment Volume (cu. ft.) = [(1.0 in.)(R_v)(A)*3630]

Where: A = Area in acres

(NOTE: R_v = the composite runoff coefficient from the RR Method. A table of R_V values and the equation for calculating a composite Rv is located in Chapter 3)

Equations 1 through 4 should be modified if the storage depths of the soil media (Max. 2–6 ft), gravel layer, or ponded water (Max. 0.5 ft.) vary in the actual design or with the addition of any surface or subsurface storage components (additional area of surface ponding, subsurface storage chambers, etc.).

Storm Water Quantity

Designers may be able to create additional surface storage by expanding the surface ponding footprint in order to accommodate a greater quantity credit for channel and/or flood protection, without necessarily increasing the soil media footprint. In other words, the engineered soil media would only underlie part of the surface area of the bioretention.

In this regard, the ponding footprint can be increased as follows to allow for additional storage:

- 50% surface area increase if the ponding depth is 6 inches or less.
- 25% surface area increase if the ponding depth is between 6 and 12 inches.

The removal of volume by bioretention changes the runoff depth entering downstream flood control facilities. An approximate approach to accounting for this in reducing the size of peak flow detention facilities is to calculate an “effective SCS curve number” (CN_{adj}), which is less than the actual curve number (CN). CN_{adj} 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. This method is detailed in Chapter 4.

Soil Infiltration Rate Testing

In order to determine if an underdrain will be needed, one shall measure the infiltration rate of subsoils at the invert elevation of the bioretention area. The infiltration rate of subsoils shall exceed 0.5 inch per hour for bioretention basins. On-site soil infiltration rate testing procedures are outlined in Appendix E. The number of soil tests varies based on the size of the bioretention area:

- < 1,000 ft^2 = 2 tests
- 1,000 – 10,000 ft^2 = 4 tests
- >10,000 ft^2 = 4 tests + 1 test for every additional 5,000 ft^2

Soil testing is not needed for Level 1 bioretention areas where an underdrain is used. If an underdrain with a gravel sump is used for Level 2, the bottom of the sump shall be at least two feet above bedrock and the seasonally high groundwater table.

Geometry

Bioretention basins shall be designed with internal flow path geometry such that the treatment mechanisms provided by the bioretention are not bypassed or short-circuited. Examples of short-circuiting include inlets or curb cuts that are very close to outlet structures (see **Figure 6.3.4**), or incoming flow that is diverted immediately to the underdrain through stone layers. Short-circuiting can be particularly problematic when there are multiple curb cuts or inlets.

Figure 6.3.4. Examples of Short-Circuiting at Bioretention Facilities *(Source: VADCR, 2010)*

For these bioretention areas to have an acceptable internal geometry, the "travel time" from each inlet to the outlet shall be maximized, and incoming flow shall be distributed as evenly as possible across the filter surface area.

One important characteristic is the length of the shortest flow path compared to the overall length, as shown in **Figure 6.3.5** below. In this figure, the ratio of the shortest flow path to the overall length is represented as:

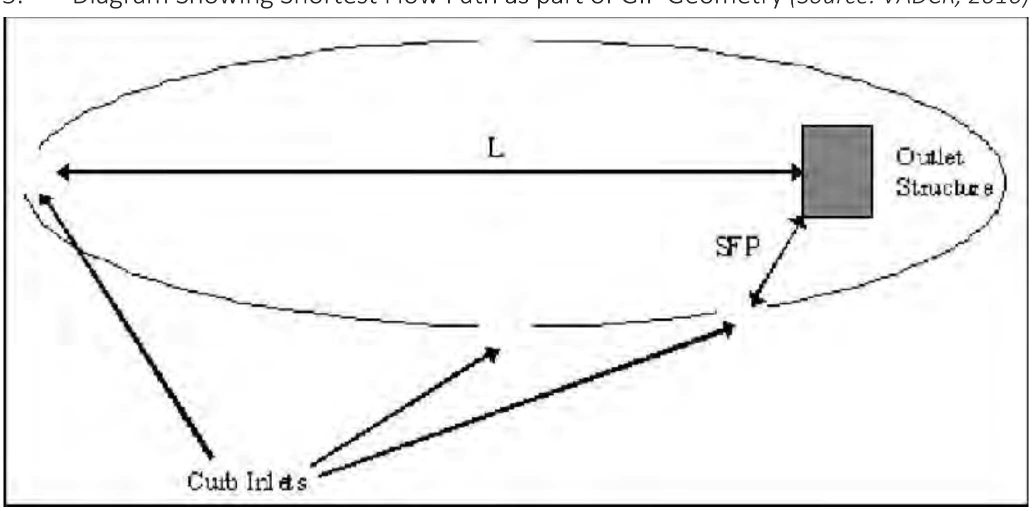
Equation 5: Ratio of Shortest Flow Path to Overall Length

$$SFP / L$$

Where:

SFP = length of the shortest flow path
L = length from the most distant inlet to the outlet

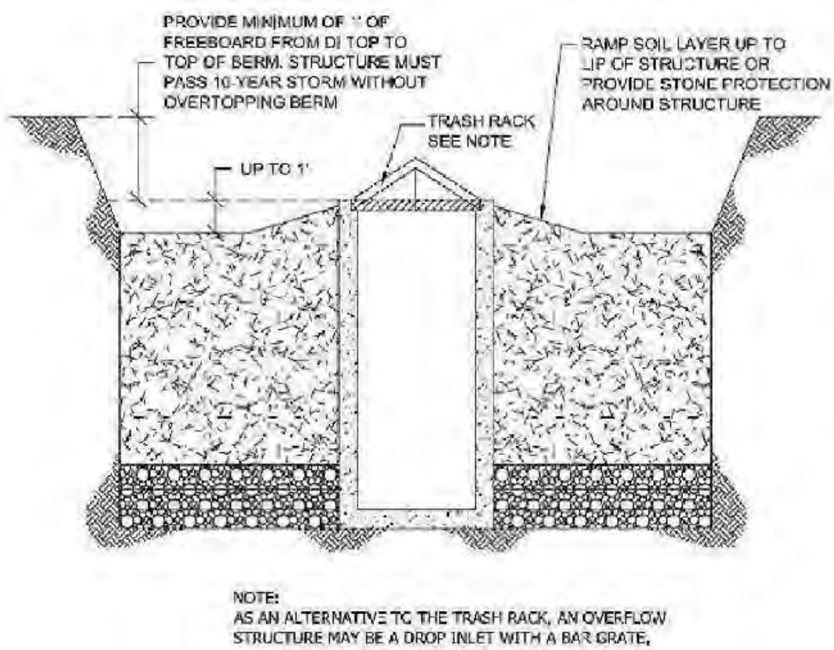
Figure 6.3.5. Diagram Showing Shortest Flow Path as part of GIP Geometry *(Source: VADCR, 2010)*



For Level 1 designs, the SFP/L ratio shall be 0.3 or greater; the ratio shall be 0.8 or greater for Level 2 designs. In some cases, due to site geometry, some inlets may not be able to meet these ratios. However, the drainage area served by such inlets shall constitute no more than 20% of the contributing drainage area. Alternately, the designer may incorporate other design features that prevent short-circuiting, including features that help spread and distribute runoff as evenly as possible across the filter surface.

Field experience has shown that soil media immediately around a raised outlet structure is prone to scouring and erosion, thus, short-circuiting of the treatment mechanism. For example, water can flow straight down through scour holes or sinkholes to the underdrain system (Hirschman et al., 2009). Design options shall be used to prevent this type of scouring. The designer should ensure that incoming flow is spread as evenly as possible across the filter surface to maximize the treatment potential. One example is shown in **Figure 6.3.6**.

Figure 6.3.6. Typical Detail of How to Prevent Bypass or Short-Circuiting Around the Overflow Structure *(Source: VADCR, 2010)*



Pre-Treatment

Pre-treatment of runoff entering bioretention areas is necessary to trap coarse sediment particles before they reach and prematurely clog the filter bed. Pre-treatment measures shall be designed to evenly spread runoff across the entire width of the bioretention area. Several pre-treatment measures are feasible, depending on the scale of the bioretention practice and whether it receives sheet flow, shallow concentrated flow, or deeper concentrated flows. A low-flow diversion or flow splitter can be used at the inlet to allow only the Treatment Volume to enter the facility. This may be achieved with a weir or curb opening sized for the target flow in combination with a bypass channel. Using a weir or curb opening helps minimize clogging and reduces the maintenance frequency. The following are appropriate pretreatment options.

For Bioretention:

- ***Pre-treatment Cells*** (channel flow): Like a forebay, this cell is located at piped inlets or curb cuts leading to the bioretention area and consists of an energy dissipater sized for the expected rates of discharge. It has a storage volume equivalent to at least 15% of the total Treatment Volume (inclusive) with a 2:1 length-to-width ratio. The cell may be formed by a wooden or stone check dam or an earthen or rock berm. Pretreatment cells do not need underlying engineered soil media, in contrast to the main bioretention cell.

- ***Grass Filter Strips*** (sheet flow): Grass filter strips extend from the edge of pavement to the bottom of the bioretention basin at a 5:1 slope or flatter. Alternatively, provide a combined 5 feet of grass filter strip at a maximum 5% (20:1) slope and 3:1 or flatter side slopes on the bioretention basin.

- ***Gravel or Stone Diaphragms*** (sheet flow). A gravel diaphragm located at the edge of the pavement shall be oriented perpendicular to the flow path to pre-treat lateral runoff, with a 2- to 4-inch drop. The stone shall be sized according to the expected rate of discharge.

- ***Gravel or Stone Flow Spreaders*** (concentrated flow). The gravel flow spreader is located at curb cuts, downspouts, or other concentrated inflow points and shall have a 2- to 4-inch elevation drop from a hard-edged surface into a gravel or stone diaphragm. The gravel shall extend the entire width of the opening and create a level stone weir at the bottom or treatment elevation of the basin.

- ***Innovative or Proprietary Structure***: An approved proprietary structure with demonstrated capability of reducing sediment and hydrocarbons may be used to provide pre-treatment.

Conveyance and Overflow

For On-line bioretention: An overflow structure shall always be incorporated into on-line designs to safely convey larger storms through the bioretention area. The following criteria apply to overflow structures:

- The overflow associated with the 100-year design storms shall be controlled so that velocities are non-erosive at the outlet point (i.e., to prevent downstream erosion).

- Common overflow systems within bioretention practices consist of an inlet structure, where the top of the structure is placed at the maximum water surface elevation of the bioretention area, which is typically 6 inches above the surface of the filter bed.

- The overflow capture device (typically a yard inlet) shall be scaled to the application – this may be a landscape grate inlet or a commercial-type structure.

- The filter bed surface shall generally be flat, so the bioretention area fills up like a bathtub.

Off-line bioretention: Off-line designs are preferred. One common approach is to create an alternate flow path at the inflow point into the structure such that when the maximum ponding depth is reached, the incoming flow is diverted past the facility. In this case, the higher flows do not pass over the filter bed and through the facility, and additional flow is able to enter as the ponding water filtrates through the soil media.

Engineered Soil Media and Surface Cover

The filter media and surface cover are the two most important elements of a bioretention facility in terms of long-term performance. The following are key factors to consider in determining an acceptable soil media mixture.

- General Filter Media Composition. The recommended bioretention soil mixture is generally classified as a loamy sand on the USDA Texture Triangle, with the following composition by volume:
    - Maximum 60% sand;
    - Less than 40% silt;
    - 5% to 10% organic matter; and
    - Less than 20% clay.

It may be advisable to start with an open-graded coarse sand material and proportionately mix in topsoil that will likely contain anywhere from 30% to 50% soil fines (sandy loam, loamy sand) to achieve the desired ratio of sand and fines. An additional 5% to 10% organic matter can then be added. (The exact composition of organic matter and topsoil material will vary, making particle size distribution and recipe for the total soil media mixture difficult to define in advance of evaluating the available material.)

- **Infiltration Rate.** The bioretention soil media shall have a minimum infiltration rate of 1 to 2 inches per hour (a proper soil mix will have an initial infiltration rate that is significantly higher).
- **Depth.** The standard minimum filter bed depth ranges from 18 to 36 inches for Level 1 and Level 2 designs, respectively. If trees are included in the bioretention planting plan, tree planting holes in the filter bed shall be deeper to provide enough soil volume for the root structure of mature trees. Use turf, perennials, or shrubs instead of trees to landscape shallower filter beds.
- **Mulch.** A 3-inch layer of mulch on the surface of the filter bed enhances plant survival, suppresses weed growth, and pre-treats runoff before it reaches the filter media. Shredded, aged hardwood mulch or pine straw make very good surface cover, as they retain a significant amount of nitrogen and typically will not float away.
- **Alternative to Mulch Cover.** In some situations, designers may consider alternative surface covers such as turf, native groundcover, erosion control matting (coir or jute matting), river stone, or pea gravel. The decision regarding the type of surface cover to use shall be based on function, cost, and maintenance.

Underdrain and Underground Storage Layer

Level 1 designs require an underdrain surrounded unless the infiltration rate of the surrounding soils is greater than 0.5 inches per hour. The underdrain shall be surrounded by a minimum of 3 inches of washed #57 stone above and on each side of the pipe. Above the stone, two inches of choking stone is needed to protect the underdrain from blockage. Some Level 2 designs will not use an underdrain (where soil infiltration rates meet minimum standards; see Table 6.3.2). For Level 2 designs with an underdrain, an underground storage layer of 12-18 inches shall be incorporated below the invert of the underdrain. The depth of the storage layer will depend on the target treatment and storage volumes needed to meet water quality criteria. However, the bottom of the storage layer shall be at least 2 feet above the seasonally high-water table and bedrock. The storage layer shall consist of clean, washed #57 stone or an approved infiltration module.

All bioretention basins shall include observation wells. The observation wells shall be tied into any T's or Y's in the underdrain system and shall extend upwards to be flush with the surface, with a vented cap. In addition, cleanout pipes shall be provided if the contributing drainage area exceeds 1 acre.

Bioretention Planting Plan

A landscaping plan shall be provided for each bioretention area. Minimum plan elements include the proposed bioretention planting plan to be used; delineation of planting areas; the planting plan, including the size, the list of planting stock, sources of plant species; and the planting sequence, including post-nursery care and initial maintenance requirements. The planting area is defined as the area disturbed by construction events. The planting plan shall address 100% of the planting area. It is highly recommended that the planting plan be prepared by a qualified landscape architect in order to tailor the planting plan to the site-specific conditions. See Appendix C for additional planting information and specifications.

Bioretention Material Specifications

Table 6.3.3 outlines the standard material specifications used to construct bioretention areas.

Table 6.3.3. Bioretention Material Specifications

Material	Specification	Notes
Filter Media Composition	Filter Media to contain a mix of topsoil, sand, and organic matter to achieve the following final composition (by volume): - Max 60% sand; - Less than 40% silt; - 5% to 10% organic matter; and - Less than 20% clay.	The volume of filter media is based on 110% of the plan volume to account for settling or compaction.
Filter Media Testing	CEC greater than 10 meq/100g	
Mulch Layer	Use mulch meeting requirements specified above.	Use mulch meeting requirements specified above.
Alternative Surface Cover	Use river stone or pea gravel, coir, and jute matting.	Use to suppress weed growth & prevent erosion.
Geotextile/Liner	Use a non-woven geotextile fabric with a flow rate of > 110 gal./min./ft^2 (e.g., Geotex 351 or equivalent).	Apply only to the sides and above the underdrain. For hotspots and certain karst sites only, use an appropriate liner on bottom.
Stone Jacket for Underdrain and/or Storage Layer	12-inch layer of 1-inch stone shall be double-washed and clean and free of all fines (e.g., #57 stone).	3 inches of washed #57 stone above and on each side of the pipe. Above the stone, two inches of choking stone.
Underdrains, Cleanouts, and Observation Wells	Use 6-inch corrugated HDPE or PVC pipe with 3/8-inch perforations at 6 inches on center; position each underdrain on a 1% or 2% slope located no more than 20 feet from the next pipe.	Lay the perforated pipe under the length of the bioretention cell, and install non-perforated pipe as needed to connect with the storm drain system. Install T's and Y's as needed, depending on the underdrain configuration. Extend cleanout pipes to the surface with vented caps at the Ts and Ys.
Plant Materials	Shrubs: Minimum 3 gal or 18-24" ht at 4' o.c. (or 1plant/15 s.f.). Grasses, sedges, perennials: Size and max. spacing as called for in Appendix C: Planting Plans. Trees: Minimum size 2" caliper, maximum spacing for Level 2 design of 1 tree/400 s.f. (NOTE: the 2" cal, minimum allows it to be counted toward landscape ordinance requirements).	Establish plant materials as specified in the landscaping plan and the recommended plant list. Alternate plant specification: When using the Forest-type planting template, Reforestation planting densities noted in Chapter 6, Section 9 may be used to meet these plant material specifications. Alternate plant specification: If a more tended look is desired, use densely-planted native meadow grasses. Annual cutting shall be required as annual maintenance.

6.3.4 Construction, Protection, and Maintenance Requirements

All GIPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all GIPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For City policies, additional guidance, and forms pertaining to GIP protection, inspection, and maintenance requirements, see Appendix B of this manual.

Requirements During Construction

- Construction equipment shall be restricted from the bioretention area to prevent compaction of the native soils.
- A dense and vigorous vegetative cover, or other effective soil stabilization practice, shall be established over the contributing pervious drainage areas before storm water can be accepted into the bioretention area. This will prevent sediment from clogging the pores in the planting media.
- Areas where GIPs will be located shall be readily identifiable and protected from unwanted encroachments during construction, both on development plans and at the construction site. Physical protection measures can include, but are not limited to, orange fencing, wood or chain link fencing, and signage. For infiltration-based practices, protection of GIP locations during construction of a land development will ensure that native soils that surround (or are within) the storm water treatment area will remain un-compacted and, therefore, continue to meet the design parameters that were specified in the approved development plan. For other practices, such as extended detention ponds, protection of GIP locations can reduce the soil compaction that typically occurs during construction, which often leads to poor soil conditions for plant growth once the GIP shall be permanently stabilized. Regardless, a lack of GIP protection will most certainly reduce or destroy the storm water functionality of the GIP once it is installed, often leading to costly corrective actions required by the City.

Protection Requirements

- Provide signage for the GIP.
    - Allows for easy identification and location of the GIP.
    - Serves as a general education tool, making those responsible for property, landscape or GIP maintenance, and the general public aware of the water quality features of the GIP and to avoid encroachment.
    - Consider using natural fencing such as graduated vegetation sizes and densities, dense shrub fencing, rocks, or other landscape features placed in a manner that discourages foot, equipment, and vehicle traffic in the storm water treatment area.
- Design the layout of the bioretention area such that maintenance access can be achieved without the need for vehicles or equipment in the storm water treatment area.
- Provide clearly marked, easily accessible and well-maintained driveways, sidewalks, and pedestrian pathways that lead vehicles, equipment, and foot traffic around the storm water treatment areas.

Inspection Requirements

- Inspect the areas where storm water flows into or out of the bioretention area for clogging or sediment buildup.
- Inspect trees, shrubs, and other vegetation to ensure they meet landscaping and vegetation specifications. Replace if necessary.
- Inspect the property that drains to the bioretention area for erosion, exposed soil, or stockpiles of other potential pollutants.

Maintenance Requirements

- Perform weeding, pruning, and trash removal as needed to maintain appearance.
- Inspect vegetation to evaluate health, replace if necessary.
- Keep inlets clear of debris to prevent clogging, clear if necessary.
- Inspect bioretention area for sediment build up, erosion, vegetative health/conditions, etc., Perform appropriate maintenance as necessary.
- Inspect underdrain cleanout to ensure storm water infiltrates properly. Clean-out underdrain if necessary.
- A densely-planted, native meadow planting plan may allow for plants to be maintained by cutting them back for a more manicured look. If this cutting is required by the Inspection, Protection, and Maintenance agreement, it shall be conducted annually, in the early spring.

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6.4 Urban Bioretention

Figure 6.4.1. Urban Bioretention Area along Indianapolis, IN Cultural Trail

DEVELOPMENT ATTRIBUTES

Construction Cost	LOW
Operation and Maintenance Cost	MODERATE
Ground-Level Encroachment	HIGH
Building Footprint Enhancement	MODERATE
Triple Bottom-Line Benefits	HIGH

Vegetated Infiltration

80% TSS Removal

Description:

Urban bioretention is similar to traditional bioretention practices, except that the urban bioretention is fit into concrete-sided containers within urban landscapes, such as planter boxes or tree planters. Captured runoff is treated by filtration through an engineered soil medium and is then either infiltrated into the subsoil or exfiltrated through an underdrain.

Variations:

- Storm water planters in landscaping areas between buildings and roadways or sidewalks
- Green Street swales and planters on street edge of sidewalk where street landscaping is normally installed
- Proprietary planting cells

Key Advantages:

- Reduced runoff volume
- Reduced peak discharge rate
- Reduced TSS
- Reduced pollutant loading
- Reduced runoff temperature
- Groundwater recharge (if soils are sufficiently permeable)
- Habitat creation
- Enhanced site aesthetics
- Reduced heat island effect

Key Limitations:

- Minimum 2-foot separations from groundwater is required
- Not suitable for pollution hotspots
- May have limited opportunities for implementation due to the amount of open space available at the site

PERFORMANCE STANDARD COMPLIANCE					
Water Quality			Stream Channel Protection	Overbank Flood Protection	Extreme Flood Protection
Treatment Volume		80% TSS Removal			
Level 1	Level 2				
56 RR Credit	Not Approved	✓	▶	▶	▶

✓ Suitable for this practice

▶ Provides partial benefits

6.4.1 General Application

Figure 6.4.2. Example Urban Bioretention Areas

Urban bioretention practices are similar in function to regular bioretention practices except they are adapted to fit into “containers” within urban landscapes. Typically, urban bioretention is installed within an urban streetscape or city street right-of-way (ROW), urban landscaping beds, tree planters, and plazas. Urban bioretention is not intended for large commercial areas nor shall it be used to treat small sub-areas of a large drainage area such as a parking lot. Rather, urban bioretention is intended to be incorporated into small fragmented drainage areas such as shopping or pedestrian plazas within a larger urban development. Urban Bioretention within the ROW can only be used to treat water that falls in the ROW. Urban bioretention features hard edges, often with vertical concrete sides, as contrasted with the gentler earthen slopes of regular bioretention. If these practices are outside of the ROW, they may be open-bottomed to allow some infiltration of runoff into the sub-grade, but they generally are served by an underdrain.

Storm water planters. Storm water planters are also known as vegetative box filters or foundation planters. They take advantage of limited space available for storm water treatment by placing a soil filter in a container located above ground or at grade in landscaping areas between buildings and roadways with liner protection (**Figure 6.4.3**). The small footprint of foundation planters is typically contained in a precast or cast-in-place concrete vault. Other materials may include molded polypropylene cells and precast modular block systems. Storm water planters shall be outside the ROW if they are treating roof water or runoff from areas outside of the ROW.

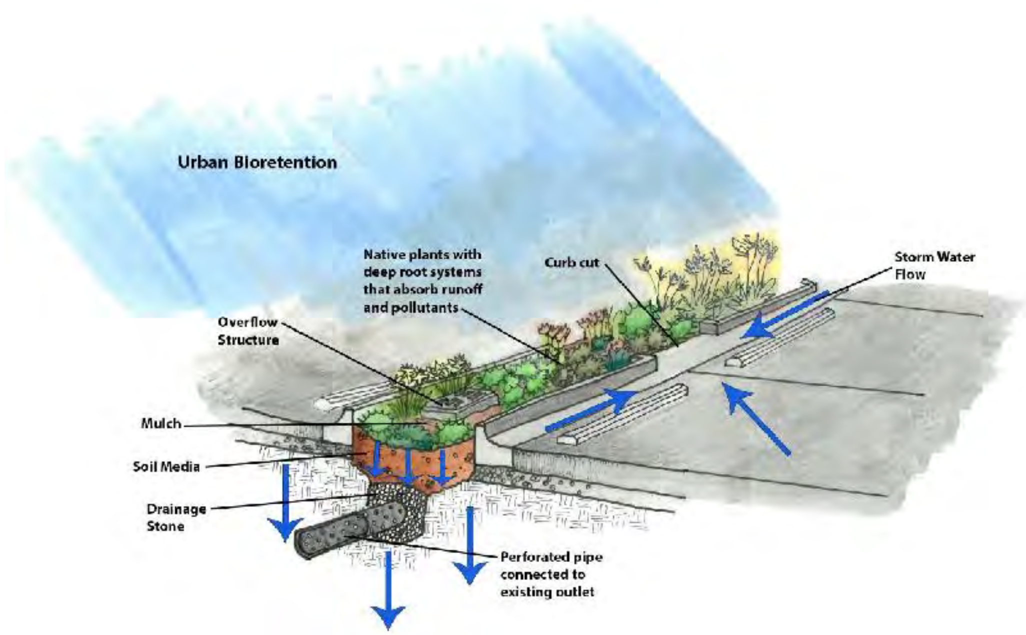
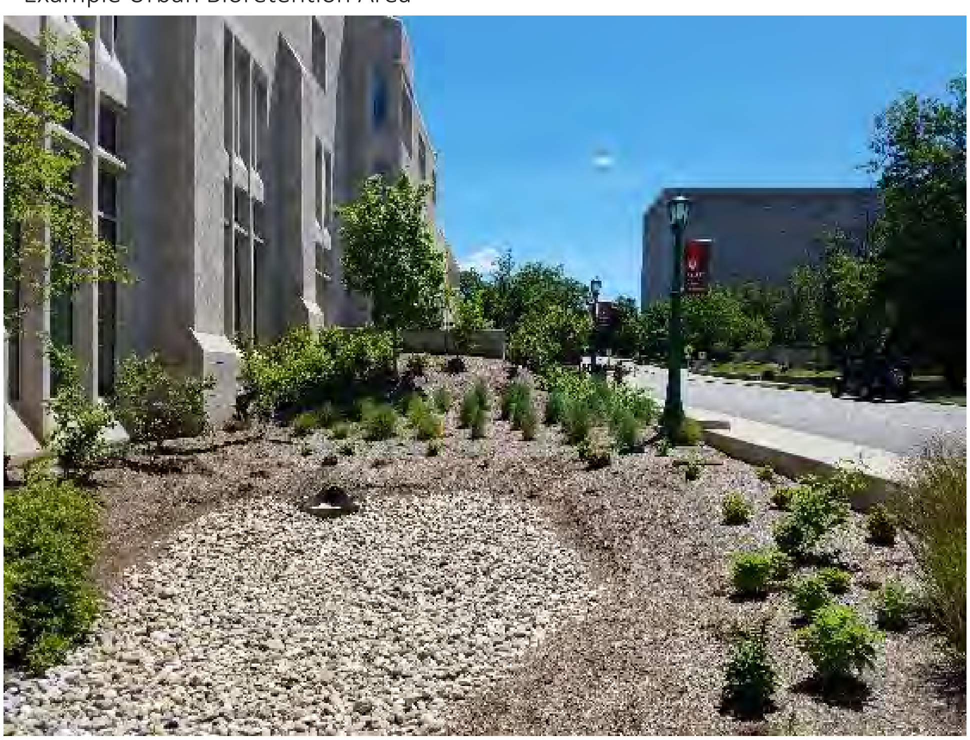


Figure 6.4.3. Planter Boxes along Residence Inn Hotel in Downtown Birmingham, AL

Green Street swales and planters. Green street swales and planters are installed in the sidewalk zone near the street where urban street trees are normally installed. The soil volume for the tree pit is increased and used as a storm water storage area (**Figure 6.4.4**). Treatment is increased by using a series of connected tree planting areas together in a row. The surface of the enlarged planting area may be mulch, grates or pervious pavement (if outside the ROW). Large and shared rooting space and a reliable water supply increase the growth and survival rates in this otherwise harsh planting environment.

Figure 6.4.4. Example Urban Bioretention Area



6.4.2 Planning and Physical Feasibility

Bioretention can be applied in most soils or topography since runoff simply percolates through an engineered soil bed and can be returned to the storm water system if the infiltration rate of the underlying soils is too low. The following criteria provided it **Table 6.4.1** shall be considered when evaluating the suitability of a bioretention area for a development site.

Table 6.4.1. Urban Bioretention Constraints

Bed Depth	Contributing Drainage Area	Hotspot Land Uses	Hydraulic Head Needed	Irrigation or Baseflow	Minimizing External Impacts	Overhead Wires
30-48" min.	2,500 sq. ft. max. (Larger drainage areas may be allowed with sufficient flow controls and other mechanisms.)	Not allowed.	3' min.	Avoid access non-storm water run-on. Irrigate if necessary for survival.	Due to urban setting, consider higher public visibility, greater trash loads, pedestrian use traffic, vandalism, vehicular loads, etc.	Tree/vegetation height shall be taken into account for overhead telephone, cable communications and power lines.
Ponding Depth	**Setbacks**	**Soils Requirement**	**Topography**	**Underdrain**	**Utility Requirement**	**Water Table Requirement**
6" max.	Impermeable barrier and underdrain required close to structures/roadways.	Assume a HSG D soil with an underdrain.	Ground surface shall slope 1% towards the outlet.	Shall be tied to ditch or conveyance system.	Consider clearance for all utilities.	2' of separation

The data listed below is necessary for the design of an urban bioretention area and shall be included with the development plan. See Appendix B for more information on required elements for the storm water management plan (SWMP).

- Existing and proposed site topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Water surface elevation of nearby water systems as well as the depth to seasonally high groundwater.
- If no underdrain is proposed for the urban bioretention area, then infiltration testing of native soils at proposed elevation of bottom of urban bioretention area is required. See Appendix E for more information.
- If no underdrain is proposed, then the Infiltration Feasibility form provided in Appendix B shall be submitted with the SWMP.

6.4.3 Design Requirements

Urban bioretention practices are similar in function to regular bioretention practices except they are adapted to fit into "containers" within urban landscapes. Therefore, special sizing accommodations are made to allow these practices to fit in very constrained areas where other surface practices may not be feasible. Level 1 design (**RR 56**) includes use of an underdrain. Level 2 design is not approved for RR. Design criteria for urban bioretention are detailed in **Table 6.4.2**.

Table 6.4.2. Urban Bioretention Design Criteria

Level 1 Design Only (RR: 56)
Sizing (Refer to sizing section below): Surface Area (sq. ft.) = Tv/Storage Depth[1] = {(1.0 inch)(Rv)(A)/12 – the volume reduced by an upstream GIP}/Storage Depth[1]
Underdrain = Schedule 40 or SDR 36 smooth wall PVC pipe with clean-outs (Refer to the Bioretention Design Specification in Appendix F)
Maximum Drainage Area = 2,500 sq. ft.
Maximum Ponding Depth = 6 inches
Filter media depth minimum = 24 inches; recommended maximum = 48 inches
Gravel layer depth minimum = 6 inches
Media and Surface Cover (Refer to Chapter 6, Section 3)
Sub-soil testing (Refer to Chapter 6, Section 3)
Inflow = sheet flow, curb cuts, trench drains, roof drains, concentrated flow, or equivalent
Building setbacks (Impermeable barrier and underdrain required close to structures/roadways)
Deeded maintenance O&M plan (Refer to Chapter 6, Section 3)

1 Storage depth is the sum of the Void Ratio (V_r) of the soil media and gravel layers multiplied by their respective depths, plus the surface ponding depth. Refer **to** Chapter 6, Section 1.

Sizing of Urban Bioretention Practices

Storm Water Quality

The required surface area of the urban bioretention filter is calculated by dividing the Treatment Volume by the Equivalent Storage Depth (Equation 1 below) in the same manner as it is calculated for traditional bioretention. The equivalent storage depth is computed as the depth of media, gravel, or surface ponding (in feet) multiplied by the accepted void ratio. See Chapter 6, Section 3 for more information on Bioretention Soil Media.

The accepted Void Ratios (V_r) are:

Bioretention Soil Media	$V_r = 0.40$ (sandy loam, loamy sand, or loam)
Gravel	$V_r = 0.40$
Surface Storage	$V_r = 1.0$

Equation 1: Urban Bioretention Equivalent Storage Depth

$$\textit{Equivalent Storage Depth} = D_E = V_{r1}(D_1) + V_{r2}(D_2) + \ldots$$

The equivalent storage depth for an urban bioretention facility with a 6-inch surface ponding depth, a 24-inch media depth, and a 12-inch gravel layer is therefore computed as:

$$D_E = (2\ ft. \times 0.40) + (1\ ft. \times 0.40) + (0.5\ ft. \times 1.0) = 1.7\ ft.$$

Where V_{r1} and D_1 are for the first layer, etc.

Surface Area (SA) is computed as:

Equation 2. Urban Bioretention Sizing

$$SA = T_v / D_E$$

Where:

SA = the surface area of the urban bioretention facility (in square feet)
D_E = Equivalent Storage Depth (ft)
T_v = the required Treatment Volume (in cubic feet)

Equation 3. Treatment Volume

$$Tv = [(1.0 \text{ inch})(Rv)(A)/12]$$

Where:

Tv = the required Treatment Volume (in cubic feet)
A = the contributing drainage area (in square feet)
R_v = Runoff Coefficient found in Chapter 3

Equations 1 and 2 should be modified if the storage depths of the soil media, gravel layer, or ponded water vary in the actual design.

Design of urban bioretention shall follow the general guidance presented in the bioretention design specification. The actual geometric design of urban bioretention is usually dictated by other landscape elements such as buildings, sidewalk widths, utility corridors, retaining walls, etc. Designers can divert fractions of the runoff volume from small impervious surfaces into urban bioretention that is integrated with the overall landscape design. Inlets and outlets shall be located as far apart as possible. The following is additional design guidance that applies to all variations of urban bioretention:

- The ground surface of the micro-bioretention cell shall slope 1% towards the outlet unless a storm water planter is used.
- The soil media depth shall be a minimum of 24 inches.
- If large trees and shrubs are to be installed, soil media depths shall accommodate.
- All urban bioretention practices shall be designed to fully drain within 24 hours.
- Any grates used above urban bioretention areas shall be removable to allow maintenance access and shall be ADA compliant.
- The inlet(s) to urban bioretention shall be stabilized using course aggregate stone, splash block, river stone or other acceptable energy dissipation measures. The following forms of inlet stabilization are recommended:
  - Stone energy dissipaters.
  - Sheet flow over a depressed curb with a 3-inch drop.
  - Curb cuts allowing runoff into the bioretention area.
  - Covered drains that convey flows under sidewalks from the curb or from downspouts (if the bioretention area is outside of the ROW).
  - Grates or trench drains that capture runoff from the sidewalk or plaza area.

- Pre-treatment options overlap with those of regular bioretention practices. However, the materials used may be chosen based on their aesthetic qualities in addition to their functional properties. For example, river rock may be used in lieu of rip rap. Other pretreatment options may include one of the following:
  - A trash rack between the pre-treatment cell and the main filter bed. This will allow trash to be collected from one location.
  - A trash rack across curb cuts. While this trash rack may clog occasionally, it keeps trash in the gutter, where it can be picked up by street sweeping equipment.
  - A pre-treatment area above ground or a manhole or grate directly over the pre-treatment area.
- Overflows can either be diverted from entering the bioretention cell or dealt with via an overflow inlet. Optional methods include the following:
  - Size curb openings to capture only the Treatment Volume and bypass higher flows through the existing gutter.
  - Use landscaping type inlets or standpipes with trash guards as overflow devices.
  - Use a pre-treatment chamber with a weir design that limits flow to the filter bed area.

In addition, the following specific design issue is applicable for storm water planters:

- Since storm water planters are often located near building foundations, waterproofing by using a watertight concrete shell or an impermeable liner is required to prevent seepage.

Green Street swales and planters are applicable along roads. They can be used along curbside in urban areas with storm water being conveyed by sheet flow or curb cuts. Green Street swales and planters can also be designed as a series of cells running parallel to roadway. An impermeable liner shall separate the road subgrade from the bioretention feature. The following specific design issues are applicable for green streets swales and planters:

- The bottom of the soil layer shall be a minimum of 4 inches below the root ball of plants to be installed.
- Green street designs sometimes cover portions of the filter media with pervious pavers (if outside the ROW) or cantilevered sidewalks. In these situations, it is important that the filter media is connected beneath the surface so that storm water and tree roots can share this space.
- Installing a tree pit grate over filter bed media is one possible solution to prevent pedestrian traffic and trash accumulation.
- Low, wrought iron fences can help restrict pedestrian traffic across the tree pit bed and serve as a protective barrier if there is a drop-off from the pavement to the micro-bioretention cell.
- A removable grate capable of supporting typical H-20 axel loads may be used to allow the tree to grow through it.
- Each tree needs a minimum of 100 square feet of shared root space.
- Proprietary tree pit devices are acceptable, provided they conform to this specification.

Please consult the bioretention design specification (Chapter 6, Section 3) for the typical materials needed for filter media, stone, mulch, and other bioretention features. In urban planters, pea gravel or river stone may be a more appropriate and attractive mulch than shredded hardwood.

The following are key factors to consider in determining an acceptable soil media mixture.

- General Filter Media Composition. The recommended bioretention soil mixture is generally classified as a loamy sand on the USDA Texture Triangle, with the following composition by volume:
    - Maximum 60% sand;
    - Less than 40% silt;
    - 5% to 10% organic matter; and
    - Less than 20% clay

The unique components for urban bioretention may include the inlet control device, a concrete box or other containing shell, protective grates, and an underdrain that daylights to another storm water practice or connects to the storm drain system. The underdrain shall:

- Consist of slotted pipe greater than or equal to 4 inches in diameter, placed in a layer of washed #57 stone above and on each side of the pipe. Above the stone, 2 inches of choking stone is needed to protect the underdrain from blockage.
- Be laid at a minimum slope of 0.5 %.
- Extend the length of the box filter from one wall to within 6 inches of the opposite wall and may be either centered in the box or offset to one side.
- Be separated from the soil media by non-woven, geotextile fabric or a 2 to 3-inch layer of 1/8 to 3/8-inch pea gravel.

Urban Bioretention Planting Plan

The degree of landscape maintenance that can be provided will determine some of the planting choices for urban bioretention areas. The planting cells can be formal gardens or naturalized landscapes. Landscaping in the ROW shall be designed to limit visual obstructions for pedestrian and vehicular traffic.

In areas where less maintenance will be provided and where trash accumulation in shrubbery or herbaceous plants is a concern, consider a "turf and trees" landscaping model. Spaces for herbaceous flowering plants can be included. This may be attractive at a community entrance location.

Native trees or shrubs are preferred for urban bioretention areas, although some ornamental species may be used. As with regular bioretention, selected perennials, shrubs, and trees shall be tolerant of drought and inundation. The landscape designer shall also take into account that de-icing materials may accumulate in the bioretention areas in winter and could kill vegetation. Additionally, tree species selected shall be those that are known to survive well in the compacted soils and polluted air and water of an urban landscape.

6.4.4 Construction, Protection, and Maintenance Requirements

All GIPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all GIPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For City policies, additional guidance, and forms pertaining to GIP protection, inspection, and maintenance requirements, see Appendix B of this manual.

Requirements During Construction

- Construction equipment shall be restricted from the urban bioretention area to prevent compaction of the native soils.
- A dense and vigorous vegetative cover, or other effective soil stabilization practice, shall be established over the contributing pervious drainage areas before storm water can be accepted into the urban bioretention area. This will prevent sediment from clogging the pores in the planting media.
- Areas where GIPs will be located shall be readily identifiable and protected from unwanted encroachments during construction, both on development plans and at the construction site. Physical protection measures can include, but are not limited to, orange fencing, wood or chain link fencing, and signage. For infiltration-based practices, protection of GIP locations during construction of a land development will ensure that native soils that surround (or are within) the storm water treatment area will remain un-compacted and, therefore, continue to meet the design parameters that were specified in the approved development plan. For other practices, such as extended detention ponds, protection of GIP locations can reduce the soil compaction that typically occurs during construction, which often leads to poor soil conditions for plant growth once the GIP is permanently stabilized. Regardless, a lack of GIP protection will most certainly reduce or destroy the storm water functionality of the GIP once it is installed often leading to costly corrective actions required by the City.

Protection Requirements

- Provide signage for the GIP.
    - Allows for easy identification and location of the GIP.
    - Serves as a general education tool, making those responsible for property, landscape, or GIP maintenance and the general public aware of the water quality features of the GIP and to avoid encroachment.
    - Consider using natural fencing such as graduated vegetation sizes and densities, dense shrub fencing, rocks, or other landscape features placed in a manner that discourages foot, equipment, and vehicle traffic in the storm water treatment area.
- Design the layout of the urban bioretention area such that maintenance access can be achieved without the need for vehicles or equipment in the storm water treatment area.
- Provide clearly marked, easily accessible, and well-maintained driveways, sidewalks, and pedestrian pathways that lead vehicles, equipment, and foot traffic around the storm water treatment areas.

Inspection Requirements

- Inspect the areas where storm water flows into or out of the urban bioretention area for clogging or sediment buildup.
- Inspect trees, shrubs, and other vegetation to ensure they meet landscaping and vegetation specifications. Replace if necessary.
- Inspect the property that drains to the urban bioretention area for erosion, exposed soil, or stockpiles of other potential pollutants.

Maintenance Requirements

- Perform weeding, pruning, and trash removal as needed to maintain appearance.
- Inspect vegetation to evaluate health; replace if necessary.
- Keep inlets clear of debris to prevent clogging; clear if necessary.
- Inspect urban bioretention area for sediment build up, erosion, vegetative health/conditions, etc. perform appropriate maintenance as necessary.
- Inspect underdrain cleanout to ensure storm water infiltrates properly. Clean-out underdrain if necessary.

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6.5 Dry Water Quality Swale/Enhanced Swale

Figure 6.5.1. Example of Dry Water Quality Swale

DEVELOPMENT ATTRIBUTES

Construction Cost	LOW
Operation and Maintenance Cost	LOW
Ground-Level Encroachment	MODERATE
Building Footprint Enhancement	MODERATE
Triple Bottom-Line Benefits	MODERATE

Vegetated Infiltration

80% TSS Removal

Description:

Vegetated open channels designed to capture and infiltrate storm water runoff within a dry storage layer beneath the base of the channel.

Variations:

- Dry water quality swale
- Enhanced swale

Key Advantages:

- Storm water treatment combined with conveyance
- Less expensive than curb and gutter
- Reduces runoff velocity
- Promotes infiltration

Key Limitations:

- Higher maintenance than curb and gutter
- Cannot be used on steep slopes
- High land requirement
- Requires 3 feet of head

PERFORMANCE STANDARD COMPLIANCE					
Water Quality			Stream Channel Protection	Overbank Flood Protection	Extreme Flood Protection
Treatment Volume		80% TSS Removal			
Level 1	Level 2				
32 RR Credit	54 RR Credit	✓	▶		

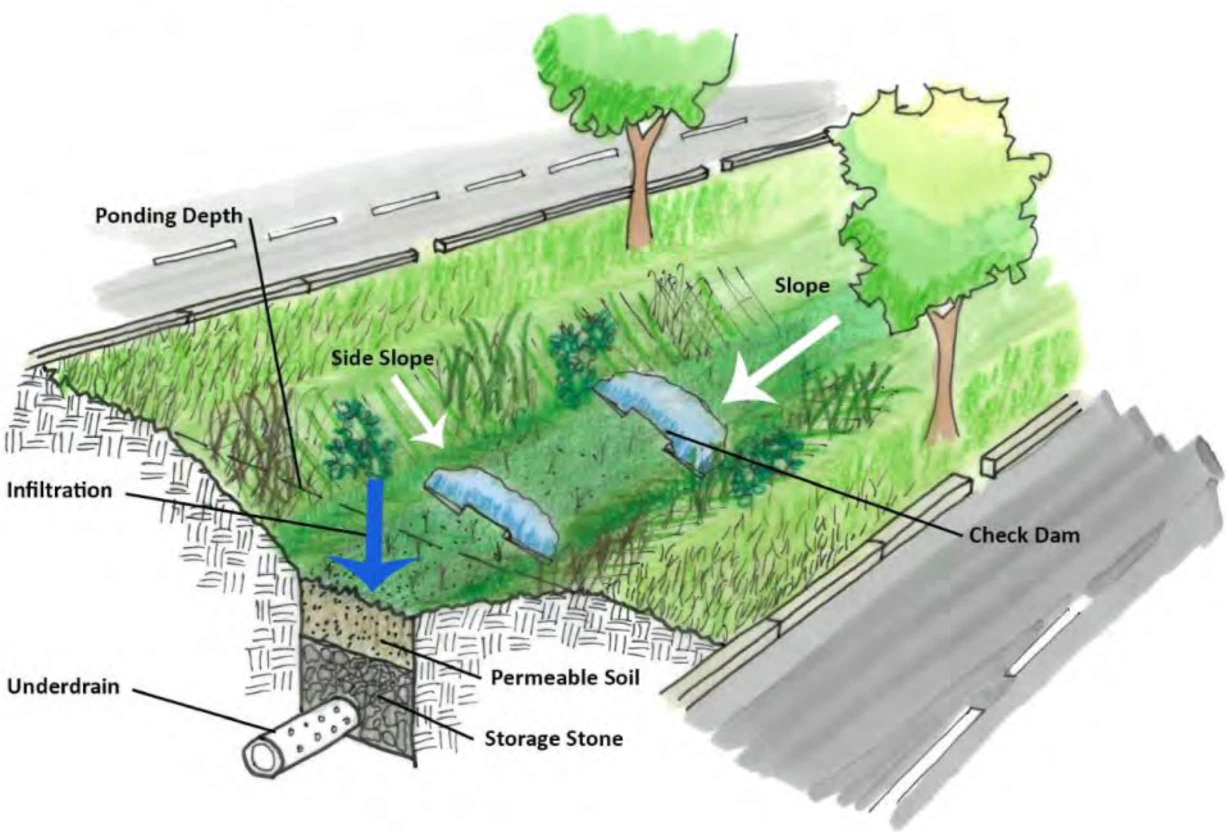
✓ Suitable for this practice

▶ Provides partial benefits

6.5.1 General Application

Water quality swales are essentially bioretention cells that are shallower, configured as linear channels, and covered with turf or other surface materials (other than mulch and ornamental plants). The water quality swale is a soil filter system that temporarily stores and then filters the desired Treatment Volume (T_v). Water quality swales rely on a pre-mixed soil media filter below the channel that is similar to that used for bioretention. If soils are extremely permeable, runoff infiltrates into underlying soils. Otherwise, the runoff treated by the soil media flows into an underdrain, which conveys treated runoff back to the conveyance system further downstream. The underdrain system consists of a perforated pipe within a gravel layer on the bottom of the swale, beneath the filter media. Water quality swales may appear as simple grass channels with the same shape and turf cover, while others may have more elaborate landscaping with native plants. Swales can be planted with turf grass, tall meadow grasses, decorative herbaceous cover, or trees.

Water Quality Swale



6.5.2 Planning and Physical Feasibility

Water quality swales can be implemented on a variety of development sites where density and topography permit their application. The following criteria provided in **Table 6.5.1** shall be considered when evaluating the suitability of a dry water quality swale/enhanced swale for a development site.

Table 6.5.1. Dry Water Quality Swale/Enhanced Swale Constraints

Community Acceptance	Contributing Drainage Area	Hotspot Land Uses	Hydraulic Capacity	Hydraulic Head Needed	Irrigation or Baseflow	Setbacks
Concerns such as grass/landscape maintenance/mowing, standing water, and mosquitoes shall be addressed though the design process and proper on-going operation and routine maintenance.	2.5 acres max. For larger drainage areas, a series of inlets and diversions are required to prevent high velocity and erosion in the channel.	Impermeable liner required.	Level 1 water quality swales shall convey the 100-yr. storm at non-erosive velocities and contain the 10-yr. storm within banks.	3' min.	Avoid access non-storm water run-on.	1' min from roadbed invert.
Soils Requirement	**Space Needed**	**Topography**	**Underdrain**	**Utility Requirement**	**Water Table Requirement**	
Infiltration rates ≤ 0.5" per hour require underdrain.	3-10% of contributing drainage area, depending on the amount of impervious cover.	2-4% longitudinal slopes. Check dams can reduce the effective slope of the swale and enhance filtering and/or infiltration. Steeper slopes adjacent to the swale shall be avoided to prevent runoff velocities that may carry a high sediment load.	Shall be tied to ditch or conveyance system.	Water/sewer lines shall be placed under pavement. Other utilities under GIP require double casing or other special protection.	2' of separation	

The data listed below is necessary for the design of a dry water quality swale/enhanced swale and shall be included with the development plan. See Appendix B for more information on required elements for the storm water management plan (SWMP).

- Existing and proposed site topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Water surface elevation of nearby water systems as well as the depth to seasonally high groundwater.
- If no underdrain is proposed for the dry water quality swale/enhanced swale, then infiltration testing of native soils at proposed elevation of bottom of dry water quality swale/enhanced swale is required. See Appendix E for more information.
- If no underdrain is proposed, then the Infiltration Feasibility form provided in Appendix B shall be submitted with the SWMP.

6.5.3 Design Requirements

Swales can be oriented to accept runoff from a single discharge point, or to accept runoff as lateral sheet flow along the swale's length. Level 1 design (RR 32) includes use of an underdrain. Level 2 design (RR 54) is an enhanced design that maximizes pollutant and runoff reduction. Design criteria for enhanced swale/water quality swale are detailed in **Table 6.5.2**.

Table 6.5.2. Enhanced Swale/Water Quality Swale Design Criteria

Level 1 Design (RR:32)	Level 2 Design (RR:54)
Sizing- See below.	Sizing- See below.
Surface Area (sq. ft.) = (Tv– the volume reduced by an upstream GIP) / Storage depth[1]	Surface Area (sq. ft.) = {(1.1)(Tv) – the volume reduced by an upstream GIP} / Storage Depth[1]
Effective swale slope ≤2%	Effective swale slope ≤1%
Media Depth minimum = 18 inches; recommended maximum = 36 inches	Media Depth minimum = 24 inches; recommended maximum = 36 inches
Sub-soil testing: one per 50 linear feet, 2 minimum; not needed if an underdrain is used; min. infiltration rate shall be > 0.5 inch/hour to remove the underdrain requirement; Refer to Appendix E for soil testing.	
Underdrain: Schedule 40 or SDR smooth wall PVC pipe with clean-outs.	Underdrain & Underground Storage Layer= (Refer to Section 4.6: Schedule 40 or SDR smooth wall PVC with clean outs, and a minimum 3-inch washed #57 stone above and on each side of the pipe and 2 inches of choking stone above that stone; OR none if the soil infiltration requirements are met (see Appendix E).
Media (Appendix E): supplied by the vendor or mixed onsite.[2]	
Inflow: sheet or concentrated flow with appropriate pre-treatment	
Pre-Treatment: a pre-treatment cell, spreader, or another approved (manufactured) grass filter strip, gravel diaphragm, or gravel flow pre-treatment structure.	
On-line design.	Off-line design or multiple treatment cells.
Planting Plan: turf grass, tall meadow grasses, native herbaceous cover, or trees	

1 The storage depth is the sum of the Void Ratio (Vr) of the soil media and gravel layers multiplied by their respective depths, plus the surface ponding depth (Refer to Appendix E).

2 Refer to Appendix E for soil specifications.

Figure 6.5.2. Example of Dry Water Quality Swale in an Urban/Office Setting

Sizing of Dry Water Quality Swales/Enhanced Swales

Storm Water Quality

Sizing of the surface area (SA) for water quality swales is based on the computed Treatment Volume (T_v) of the contributing drainage area and the storage provided within the swale media and gravel layers and behind check dams. The required surface area (in square feet) is computed as the Treatment Volume (in cubic feet) divided by the equivalent storage depth (in feet). The equivalent storage depth is computed as the depth of the soil media, the gravel, and surface ponding (in feet) multiplied by the accepted void ratio.

The accepted Void Ratios (V_r) are:

Water Quality Swale Soil Media	$V_r = 0.40$
Gravel V_r	$V_r = 0.40$
Surface Storage behind check	$V_r = 1.0$

The equivalent storage depth for the Level 1 design (without considering surface ponding) is computed as:

Equation 1. Equivalent Storage Depth – Level 1

$$\text{Equivalent Storage Depth} = D_E = V_r\ (D_1) + V_r\ (D_2) + \cdots$$

$$D_E = (1.5 \text{ ft.} \times 0.40) + (0.25 \text{ ft.} \times 0.40) = 0.7 \text{ ft.}$$

And the equivalent storage depth for the Level 2 design (without considering surface ponding) is computed as:

Equation 2. Equivalent Storage Depth – Level 2

$$\text{Equivalent Storage Depth} = D_E = V_r\ (D_1) + V_r\ (D_2) + \cdots$$

$$D_E = (2.0 \text{ ft.} \times 0.40) + (1.0 \text{ ft.} \times 0.40) = 1.2 \text{ ft.}$$

The effective storage depths will vary according to the actual design depths of the soil media and gravel layer.

Note: When using Equations 3 or 4 below to calculate the required surface area of a water quality swale that includes surface ponding (with check dams), the storage depth calculation (Equation 1 or 2) shall be adjusted accordingly.

The Level 1 Water Quality Swale Surface Area (SA) is computed as:

Equation 3. Surface Area – Level 1

SA (sq. ft.) = (Tv – the volume reduced by an upstream GIP) / D_E ft.

And the Level 2 Water Quality Swale SA is computed as:

Equation 4. Surface Area – Level 2

SA (sq. ft.) = [(1.1 * T_v) – the volume reduced by an upstream GIP]/ D_E ft.

NOTE: The volume reduced by upstream PTPs is supplemented with the anticipated volume of storage created by check dams along the swale length.

Where:

SA = Minimum surface area of Water Quality Swale (sq. ft.)
T_v = Treatment Volume (cu. ft.) = [(1 inch)(R_v)(A)]*3630
A= Area in acres.

The final water quality swale design geometry will be determined by dividing the SA by the swale length to compute the required width; or by dividing the SA by the desired width to compute the required length.

Soil Infiltration Rate Testing

The second key sizing decision is to measure the infiltration rate of subsoils below the water quality swale area to determine if an underdrain will be needed. The infiltration rate of the subsoil shall exceed 0.5 inches per hour to avoid installation of an underdrain. The acceptable methods for on-site soil infiltration rate testing are outlined in Appendix E. A soil test shall be conducted for every 50 linear feet of water quality swale, with a minimum of two tests per swale.

Water Quality Swale Geometry

Design guidance regarding the geometry and layout of water quality swales is provided below.

Shape. A parabolic shape is preferred for water quality swales for aesthetic, maintenance, and hydraulic reasons. However, the design may be simplified with a trapezoidal cross-section, as long as the soil filter bed boundaries lay in the flat bottom areas.

Side Slopes. The side slopes of water quality swales shall be no steeper than 3H:1V for maintenance considerations (i.e., mowing). Flatter slopes are encouraged where adequate space is available to enhance pre-treatment of sheet flows entering the swale. Swales shall have a bottom width from 2 to 8 feet to ensure that an adequate surface area exists along the bottom of the swale for filtering. If a swale will be wider than 8 feet, the designer shall incorporate berms, check dams, level spreaders, or multi-level cross-sections to prevent braiding and erosion of the swale bottom.

Swale Longitudinal Slope. The longitudinal slope of the swale shall be moderately flat to permit the temporary ponding of the Treatment Volume within the channel. The recommended swale slope is less than or equal to 2% for a Level 1 design and less than or equal to 1% for a Level 2 design, though slopes up to 4% are acceptable if check dams are used. The minimum recommended slope for an on-line water quality swale is 0.5%. Refer to **Table 6.5.3** for check dam spacing based on the swale longitudinal slope.

Table 6.5.3. Typical Check Dam (CD) Spacing to Achieve Effective Swale Slope

Swale Longitudinal Slope	LEVEL 1	LEVEL 2
	Spacing[1] of 12-inch High (max.) Check Dams[2] to Create an Effective Slope of 2%	Spacing[1] of 12-inch High (max.) Check Dams[2] to Create an Effective Slope of 0 to 1%
0.5%	–	200 ft. to –
1.0%	–	100 ft. to –
1.5%	–	67 ft. to 200 ft.
2.0%	–	50 ft. to 100 ft.
2.5%	200 ft.	40 ft. to 67 ft.
3.0%	100 ft.	33 ft. to 50 ft.
3.5%	67 ft.	30 ft. to 40 ft.
4.0%	50 ft.	25 ft. to 33 ft.

1 The spacing dimension is half of the above distances if a 6-inch check dam is used.
2 Check dams require a stone energy dissipater at the downstream toe.

Check dams: Check dams shall be firmly anchored into the side-slopes to prevent outflanking and be stable during the 10-year storm design event. The height of the check dam relative to the normal channel elevation shall not exceed 12 inches. Each check dam shall have a minimum of one weep hole or a similar drainage feature, so it can dewater after storms. Armoring may be needed behind the check dam to prevent erosion. The check dam shall be designed to spread runoff evenly over the water quality swale's filter bed surface, through a centrally located depression with a length equal to the filter bed width. In the center of the check dam, the depressed weir length shall be checked for the depth of flow and sized for the appropriate design storm. Check dams shall be constructed of wood, stone, or concrete.

Ponding Depth: Drop structures or check dams can be used to create ponding cells along the length of the swale. The maximum ponding depth in a swale shall not exceed 12 inches at the most downstream point.

Drawdown: Water quality swales shall be designed so that the desired Treatment Volume is completely filtered within 24 hours or less. This drawdown time can be achieved by using the appropriate soil media mix and an underdrain along the bottom of the swale, or native soils with adequate permeability, as verified through testing (see Section 4.6).

Underdrain: Underdrains are provided in water quality swales to ensure that they drain properly after storms. The underdrain shall be constructed of 4-inch or larger diameter perforated Schedule 40 or SDR 35 smooth wall PVC, which is placed on 3-inch layer of double-washed gravel (ALDOT #57). The underdrain shall be encased in a gravel layer extending at least 3 inches above the surface of the pipe. This gravel layer shall be covered with a 3-inch layer of choker stone (ALDOT #8 or #89), which is then covered with a permeable geotextile.

Pre-Treatment

Several pre-treatment measures are feasible, depending on whether the specific location in the water quality swale system will be receiving sheet flow, shallow concentrated flow, or fully concentrated flow:

Initial Sediment Forebay (channel flow): This grass cell is located at the upper end of the water quality swale segment with a 2:1 length to width ratio and a storage volume equivalent to at least 15% of the total Treatment Volume.

Check Dams (channel flow): These energy dissipation devices are acceptable as pre-treatment on small swales with drainage areas of less than 1 acre.

Tree Check Dams (channel flow): These are street tree mounds that are placed within the bottom of a water quality swale up to an elevation of 9 to 12 inches above the channel invert. One side has a gravel or river stone bypass to allow storm runoff to percolate through.

Grass Filter Strip (sheet flow): Grass filter strips extend from the edge of the pavement to the bottom of the water quality swale at a 5:1 slope or flatter. Alternatively, provide a combined 5 feet of grass filter strip at a maximum 5% (20:1) slope and 3:1 or flatter side slopes on the water quality swale.

Gravel Diaphragm (sheet flow): A gravel diaphragm located at the edge of the pavement shall be oriented perpendicular to the flow path to pre-treat lateral runoff, with a 2 to 4-inch drop. The stone shall be sized according to the expected rate of discharge.

Pea Gravel Flow Spreader (concentrated flow): The gravel flow spreader is located at curb cuts, downspouts, or other concentrated inflow points and shall have a 2 to 4-inch elevation drop from a hard-edged surface into a gravel or stone diaphragm. The gravel shall extend the entire width of the opening and create a level stone weir at the bottom or treatment elevation of the swale.

Conveyance and Overflow

The bottom width and slope of a water quality swale shall be designed such that the velocity of flow from a 1-inch rainfall will not exceed 3 feet per second. Check dams may be used to achieve the needed runoff reduction volume, as well as to reduce the flow. Check dams shall be spaced based on channel slope and ponding requirements, consistent with the criteria in Table 6.5.3.

The swale shall also convey the 2- and 10-year storms at non-erosive velocities with at least 6 inches of freeboard. The analysis shall evaluate the flow profile through the channel at normal depth, as well as the flow depth over top of the check dams.

Water quality swales may be designed as off-line systems, with a flow splitter or diversion to divert runoff in excess of the design capacity to an adjacent conveyance system. Or, strategically placed overflow inlets may be placed along the length of the swale to periodically pick up water and reduce the hydraulic loading at the downstream limits.

Filter Media: Water quality swales require replacement of native soils with a prepared soil media. The soil media provides adequate drainage, supports plant growth, and facilitates pollutant removal within the water quality swale. At least 18 inches of soil media shall be added above the choker stone layer to create an acceptable filter. The mixture for the soil media is identical to that used for bioretention (Chapter 6, Section 3) (refer to Appendix E for additional soil media specifications).

Underdrain and Underground Storage Layer: Some Level 2 water quality swale designs will not use an underdrain [(where soil infiltration rates meet minimum standards (see Table 6.5.2)]. For Level 2 designs with an underdrain, an underground storage layer, consisting of a minimum 12 inches of stone, shall be incorporated below the invert of the underdrain. The depth of the storage layer will depend on the target treatment and storage volumes needed to meet water quality criteria. However, the bottom of the storage layer shall be at least 2 feet above the seasonally high groundwater table and bedrock. The storage layer shall consist of clean, washed #57 stone or an approved infiltration module.

A water quality swale shall include observation wells with cleanout pipes along the length of the swale if the contributing drainage area exceeds 1 acre. The wells shall be tied into any T's or Y's in the underdrain system and shall extend upwards to be flush with surface, with a vented cap.

Landscaping and Planting Plan: Designers shall choose grasses, herbaceous plants or trees that can withstand both wet and dry periods and relatively high velocity flows for planting within the channel. Salt tolerant grass species shall be chosen for water quality swales receiving drainage from areas treated for ice in winter. Taller and denser grasses are preferable, although the species is less important than good stabilization and dense vegetative cover. Grass species shall have the following characteristics: a deep root system to resist scouring, a high stem density with well-branched top growth, water-tolerance, resistance to being flattened by runoff, and an ability to recover growth following inundation. A qualified landscape designer shall be consulted for selection of appropriate plantings. See Appendix C for additional planting information and specifications.

Water Quality Swale Material Specifications

Table 6.5.4 outlines the standard material specifications for constructing water quality swales.

Table 6.5.4. Water Quality Swale Material Specifications

Material	Specification	Notes
Filter Media Composition	Filter Media to contain (by volume): 30-70% sand < 40% silt 5-10% organic matter < 20% clay.	The volume of filter media is based on 110% of the product of the surface area and the media depth, to account for settling.
Filter Media Testing	Mix on-site or procure from an approved media vendor (refer to Chapter 6, Section 3: Bioretention, for additional soil media information).	
Filter Fabric	A non-woven polypyrene geotextile with a flow rate of > 110 gal./min./sq. ft. (e.g., Geotex 351 or equivalent); Apply immediately above the underdrain only.	

Material	Specification	Notes
Choking Layer	A 3-inch layer of choker stone (typically #8 or # 89 washed gravel) laid above the underdrain stone.	
Stone and/or Storage Layer	A 12 to 18-inch layer (depending on the desired depth of the storage layer) of #57 stone shall be double-washed and clean and free of all soil and fines.	
Underdrains, Cleanouts, and Observation Wells	4-inch or larger Schedule 40 or SDR 35 smooth wall PVC with 3/8-inch perforations.	If needed, install perforated pipe for the full length of the water quality swale. Use non-perforated pipe, as needed, to connect with the storm drain system.
Vegetation	Plant species as specified on the landscaping plan.	
Check Dams	Use non-erosive material such as wood, gabions, riprap, or concrete. All check dams shall be underlain with filter fabric and include weep holes. Wood used for check dams shall consist of pressure-treated logs or timbers, or water-resistant tree species such as cedar, hemlock, swamp oak, or locust.	
Erosion Control Fabric	Where flow velocities dictate, use woven biodegradable erosion control fabric or mats that are durable enough to last at least 2 growing seasons.	

6.5.4 Construction, Protection, and Maintenance Requirements

All GIPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all GIPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For City policies, additional guidance, and forms pertaining to GIP protection, inspection, and maintenance requirements, see Appendix B of this manual.

Requirements During Construction

- Construction equipment shall be restricted from the dry water quality swale/enhanced swale area to prevent compaction of the native soils.
- A dense and vigorous vegetative cover, or other effective soil stabilization practice, shall be established over the contributing pervious drainage areas before storm water can be accepted into the dry water quality swale/enhanced swale. This will prevent sediment from building up in the GIP.
- Areas where GIPs will be located shall be readily identifiable and protected from unwanted encroachments during construction, both on development plans and at the construction site. Physical protection measures can include, but are not limited to, orange fencing, wood or chain link fencing, and signage. For infiltration-based practices, protection of GIP locations during construction of a land development will ensure that native soils that surround (or are within) the storm water treatment area will remain un-compacted and, therefore, continue to meet the design parameters that were specified in the approved development plan. For other practices, such as extended detention ponds, protection of GIP locations can reduce the soil compaction that typically occurs during construction, which often leads to poor soil conditions for plant growth once the GIP shall be permanently stabilized. Regardless, a lack of GIP protection will most certainly reduce or destroy the storm water functionality of the GIP once it is installed, often leading to costly corrective actions required by the City.

Protection Requirements

- Provide signage for the GIP.
    - Allows for easy identification and location of the GIP.

- Serves as a general education tool, making those responsible for property, landscape or GIP maintenance, and the general public aware of the water quality features of the GIP and to avoid encroachment.
- Consider using natural fencing such as graduated vegetation sizes and densities, dense shrub fencing, rocks, or other landscape features placed in a manner that discourages foot, equipment, and vehicle traffic in the storm water treatment area.

❖ Design the layout of the dry water quality swale/enhanced swale such that maintenance access can be achieved without the need for vehicles or equipment in the storm water treatment area.

❖ Provide clearly marked, easily accessible and well-maintained driveways, sidewalks, and pedestrian pathways that lead vehicles, equipment, and foot traffic around the storm water treatment areas.

Inspection Requirements

❖ Inspect the areas where storm water flows into or out of the dry water quality swale/enhanced swale for clogging or sediment buildup.

❖ Inspect trees, shrubs, and other vegetation to ensure they meet landscaping and vegetation specifications. Replace if necessary.

❖ Inspect the property that drains to the dry water quality swale/enhanced swale for erosion, exposed soil, or stockpiles of other potential pollutants.

Maintenance Requirements

❖ Perform weeding, pruning, and trash removal as needed to maintain appearance.

❖ Inspect vegetation to evaluate health, replace if necessary.

❖ Keep inlets clear of debris to prevent clogging, clear if necessary.

❖ Inspect dry water quality swale/enhanced swale area for sediment build up, erosion, vegetative health/conditions, etc. Perform appropriate maintenance as necessary.

❖ Inspect underdrain cleanout to ensure storm water infiltrates properly. Clean-out underdrain if necessary.

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6.6 Downspout Disconnection

Vegetated Infiltration | 80% TSS Removal

Figure 6.6.1. Example of Residential Downspout Extender to Pervious Surface

DEVELOPMENT ATTRIBUTES

Construction Cost	LOW
Operation and Maintenance Cost	LOW
Ground-Level Encroachment	MODERATE
Building Footprint Enhancement	MODERATE
Triple Bottom-Line Benefits	MODERATE

Description:

Refers to disconnecting roof downspouts and directing flow away from storm sewer inlets and impervious areas such as driveways, parking lots, and roads that provide direct connections to a public storm water system and directing them instead to a storage facility or pervious areas for infiltration. Downspouts can be directed to vegetated areas, bioretention areas, infiltration trenches, or cisterns.

Due to the difficulty of regulation and oversight, no credit for downspout disconnections is provided for residential grading permit projects unless they are included within a common area of a sub-division constructed with green infrastructure features. Additionally, protection and maintenance guidance should be included in the home owner's association's operation and maintenance agreement.

Variations:

- Simple disconnection
- Disconnection leading to an alternative runoff reduction practice(s)

Key Advantages:

- Cost effective
- Promotes infiltration, reducing runoff volume, and peak discharge
- Vegetated areas for infiltration provide aesthetics
- Increases public awareness and involvement

Key Limitations:

- Requires owner buy-in and maintenance to ensure proper drainage
- May require large on-lot pervious areas
- Shall avoid causing foundation flooding or ice hazards

PERFORMANCE STANDARD COMPLIANCE					
Water Quality			Stream Channel Protection	Overbank Flood Protection	Extreme Flood Protection
Treatment Volume		80% TSS Removal			
Level 1	Level 2				
15%[1]	43%[1]	✓	▶	▶	▶

✓ Suitable for this practice

▶ Provides partial benefits

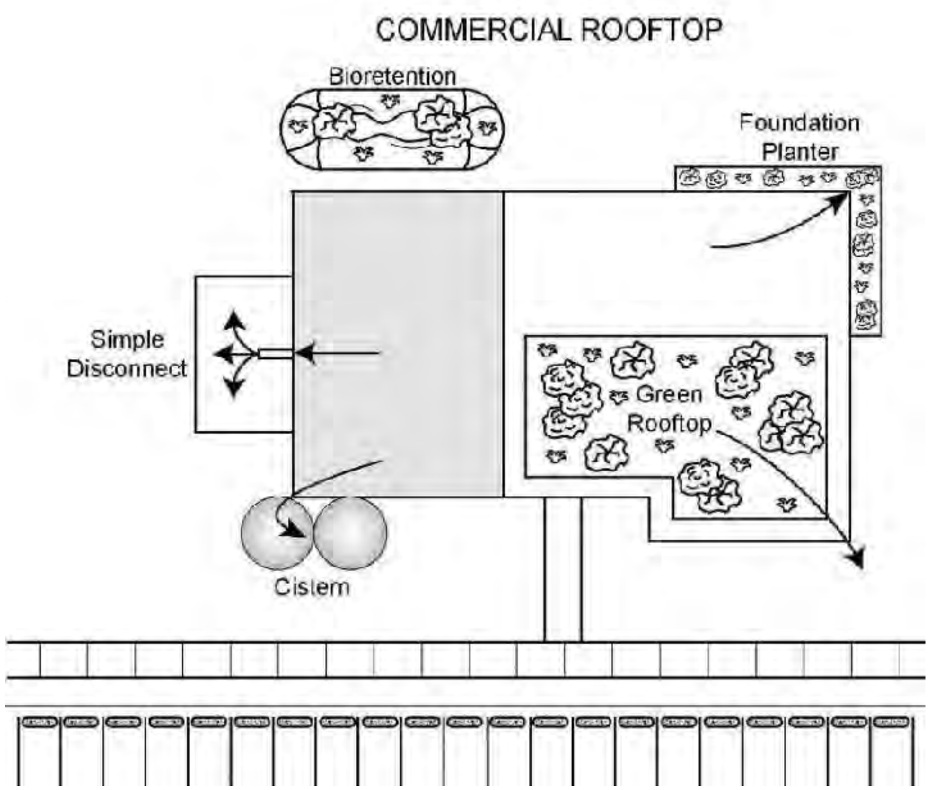
1 Refer to Table 6.6.2.

6.6.1 General Application

The strategy of downspout disconnection involves managing runoff close to its source by intercepting, infiltrating, filtering, treating, or reusing it as it moves from the impervious surface to the drainage system. Two kinds of disconnection are allowed (**Figure 6.6.2**):

- Simple disconnection, whereby rooftops and/or on-lot residential impervious surfaces are directed to pervious areas (e.g., turf, meadow, or woods), or
- Disconnection leading to an alternative runoff reduction practice(s) adjacent to the roof.

Figure 6.6.2. Roof Disconnection with Alternative Runoff Reduction Practices *(Source: VADCR, 2011)*



6.6.2 Planning and Physical Feasibility

The following criteria provided in **Table 6.6.1** shall be considered when evaluating the suitability of downspout disconnection for a development site.

Table 6.6.1. Downspout Disconnection Constraints

Contributing Drainage Area	Flow Path	Setbacks
1,000 square feet of roof area to any one point	75 ft max.	Extend downspouts 5 ft. (15 ft. in karst areas) away from building if grade is less than 1%.
Site Topography Needed	Soil	Topography
<2% or <5% with turf reinforcement	Appropriate for all HSGs. For C or D soils, alternative runoff reduction practices (e.g., compost-amended filter path, bioretention, rainwater harvesting) can boost the runoff reduction rate.	Not permitted on slopes over 2%, over 5% with turf reinforcement, or within 500 ft. of steep slopes or landslide-prone areas.

The data listed below is necessary for the design of downspout disconnection and shall be included with the development plan. See Appendix B for more information on required elements for the development plan.

- Existing and proposed site, topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Water surface elevation of nearby water systems as well as the depth to seasonally high groundwater.
- Infiltration testing of native soils at proposed elevation of bottom of downspout disconnection area.

6.6.3 Design Requirements

The major design goal for downspout disconnection is to maximize runoff volume reduction and pollutant removal. In sites with C or D soils, Level 1 **RR is 15%** and in sites with A or B soils, **RR is 43%**. To maximize pollutant and runoff reduction, designers may choose to add an alternative practice to increase the RR. Design criteria for Level 1 and Level 2 downspout disconnection are summarized in **Table 6.6.2**. Typical details are located in Appendix F**.**

Table 6.6.2. Annual Runoff Volume Reduction Provided by Rooftop Disconnection[1]

FUNCTION PROVIDED BY SIMPLE ROOFTOP DISCONNECTION	Level 1 HSG Soils C and D	Level 2 HSG SOILS A and B
Annual Runoff Volume Reduction (RR)	15%	43%
NOTE: Storm water functions of disconnection can assume a greater runoff reduction rate by employing an acceptable alternative runoff reduction practice. Acceptable practices and their associated runoff reduction rates are listed below. Designers shall consult the applicable appendix or GIP section for design standards.		
Alternative Practice	GIP No.	Runoff Reduction Rate[2]
Soil compost-amended filter path	See Appendix E	50%
Infiltration trench – Level 1	Chapter 6, Section 12	43%
Infiltration trench – Level 2	Chapter 6, Section 12	89%
Bioretention – Level 1	Chapter 6, Section 3	56%
Bioretention – Level 2	Chapter 6, Section 3	78%
Cistern	Chapter 6, Section 13	Defined by user
Urban Bioretention	Chapter 6, Section 4	56%

1 CSN (2008), CWP (2007)
2 When disconnecting a rooftop, it is possible to amend the soil or have the runoff flow into another GIP to improve volume reduction performance. If an alternative practice is employed, the runoff reduction rate assigned to the alternative practice shall be used, instead of the RR assigned to Level 1 or Level 2 soils.

Alternative Practices to Enhance Downspout Disconnection

Soil Compost-Amended Filter Path

The incorporation of compost amendments results in a **RR of 50%**. The compost amendment shall conform to Appendix E and include the following design elements:

- Flow from the downspout shall be spread over a 10-foot wide strip extending down-gradient along the flow path from the building to the street or conveyance system.

- ❖ The filter path shall be at least 20 feet in length.
- ❖ A pea gravel or river stone diaphragm, or other accepted flow spreading device shall be installed at the amended soil path inlet to distribute flows evenly across the filter path.
- ❖ The strip shall be lower than the surrounding land area to keep flow in the filter path. Similarly, the flow area of the filter strip shall be laterally level to discourage concentrating the flow down the middle of the filter path.
- ❖ Use 2 to 4 inches of compost and till to a depth of 6 to 10 inches within the filter path.

Infiltration Trench

Designers may choose to use infiltration as an alternative practice to compliment downspout disconnection and meet the requirements of a Level 1 baseline design or choose an enhanced design (Level 2) that maximizes runoff reduction, as described in Chapter 6, Section 12. Combining a Level 1 infiltration trench with downspout disconnection will results in a RR of 43% and combining it with a Level 2 infiltration trench will result in a RR of 89%. The infiltration trench shall conform to Chapter 6, Section 12.

Bioretention

Designers may choose to use bioretention or urban bioretention as an alternative practice to compliment downspout disconnection and meet the requirements of a Level 1 baseline design or choose an enhanced design (Level 2) that maximizes runoff reduction, as described in Chapter 6, Sections 3 or 4. Combining a Level 1 bioretention area with downspout disconnection will results in a RR of 56%, and combining it with a Level 2 bioretention area will result in a RR of 78%. Combining an urban bioretention area with downspout disconnection will results in a RR of 56%. The bioretention or urban bioretention area shall conform to Chapter 6, Sections 3 or 4.

Cisterns

Designers may choose to use a cistern as an alternative practice to compliment downspout disconnection and meet the requirements of a Level 1 baseline design or choose an enhanced design (Level 2) that maximizes runoff reduction, as described in Chapter 6, Section 13. The resulting RR is dependent on tank size, configuration, demand drawdown, and use of secondary practices (refer to Chapter 6, Section 13). The cistern shall conform to Chapter 6, Section 13.

6.6.4 Construction, Protection, and Maintenance Requirements

All GIPs require proper construction, protection, and long-term maintenance, or they will not function as designed and may cease to function altogether. The design of all GIPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For City policies, additional guidance, and forms pertaining to GIP protection, inspection, and maintenance requirements, see Appendix B of this manual.

Requirements During Construction

- ❖ Simple erosion and sediment control measures, such as temporary seeding and erosion control mats, shall be used within the pervious areas located below downspout disconnects.
- ❖ To help prevent soil compaction, heavy vehicular and foot traffic shall be kept out of the pervious areas located below downspout disconnects during and after construction.
- ❖ Construction contracts shall contain a replacement warranty that covers at least three growing seasons to help ensure adequate growth and survival of the vegetation planted within the pervious area located below a downspout disconnect.

- Areas where GIPs will be located shall be readily identifiable and protected from unwanted encroachments during construction, both on development plans and at the construction site. Physical protection measures can include, but are not limited to, orange fencing, wood or chain link fencing, and signage. For infiltration-based GIPs, protection of GIP locations during construction of a land development will ensure that native soils that surround (or are within) the storm water treatment area will remain un-compacted and, therefore, continue to meet the design parameters that were specified in the approved development plan. For other GIPs, such as extended detention ponds, protection of GIP locations can reduce the soil compaction that typically occurs during construction, which often leads to poor soil conditions for plant growth once the GIP must be permanently stabilized. Regardless, a lack of GIP protection will most certainly reduce or destroy the storm water functionality of the GIP once it is installed, often leading to costly corrective actions required by the City.

Protection Requirements

- Provide signage for the GIP.
    - Allows for easy identification and location of the GIP.
    - Serves as a general education tool, making those responsible for property, landscape, or GIP maintenance and the general public aware of the water quality features of the GIP and to avoid encroachment.
    - Consider using natural fencing such as graduated vegetation sizes and densities, dense shrub fencing, rocks, or other landscape features placed in a manner that discourages foot, equipment, and vehicle traffic in the storm water treatment area.
- Design the layout of the downspout disconnection area such that maintenance access can be achieved without the need for vehicles or equipment in the storm water treatment area.
- Provide clearly marked, easily accessible, and well-maintained driveways, sidewalks, and pedestrian pathways that lead vehicles, equipment, and foot traffic around the pervious area located below the disconnected downspout.

Inspection Requirements

- Downspouts shall provide stable conveyance.
- Ensure that storm water enters pervious area as sheet flow.
- Inspect vegetation to ensure it meets landscaping and vegetation specifications. Replace if necessary.
- Inspect for excessive trash, debris, sedimentation, oil, chemicals, accumulation at inflow points. Remove if necessary.
- Inspect for evidence of erosion at/around inflow point, downspouts, or surface impervious area drains to the receiving pervious area. Immediately stabilize any areas of bare soil.

Maintenance Requirements

- Remove any excess trash, debris, and sedimentation from the downspout disconnect flow path area.
- Clean gutters at least twice a year and more often if there are overhanging trees.
- Check and clear elbows or bending in downspouts to prevent clogging.
- Remove any invasive species or weeds from the downspout disconnect flow path area.
- If dead vegetation or exposed soil is present, replace per plans.
- Ensure treatment area retains dimensions as shown on plans and is in good condition.

References

Chesapeake Stormwater Network (CSN). 2008. *Technical Bulletin 1: Stormwater Design Guidelines for Karst Terrain in the Chesapeake Bay Watershed.* Version 1.0. Baltimore, MD. Available online at: http://www.chesapeakestormwater.net/all-things-stormwater/stormwater-guidance-for-karst-terrain-in-the-chesapeake-bay.html

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CWP. 2007. *National Pollutant Removal Performance Database Version 3.0*. Center for Watershed Protection, Ellicott City, MD.

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VADCR. 2011. Stormwater Design Specification No. 1: Rooftop (Impervious Surface) Disconnection, Version 1.9, March 1, 2011. Virginia Department of Conservation and Recreation. Available at: http://vwrrc.vt.edu/swc/NonProprietaryBMPs.html.

6.7 Grass Channel/Open Channel

Intrinsic GIP

Figure 6.7.1. Example of Grass Channel

DEVELOPMENT ATTRIBUTES

Construction Cost	LOW
Operation and Maintenance Cost	LOW
Ground-Level Encroachment	MODERATE
Building Footprint Enhancement	MODERATE
Triple Bottom-Line Benefits	LOW

Description:

Limited application structural control intended for small drainage areas. Open channels that are vegetated and are designed to filter storm water runoff through settling and biological uptake mechanisms, as well as to slow water for treatment by another structural control.

Variations:

- Grass channel
- Open channel

Key Advantages:

- Provides pre-treatment if used as part of runoff conveyance system
- Provides partial infiltration of runoff in pervious soils
- Cost effective – less expensive than curb and gutter
- Good for small drainage areas
- Wildlife habitat potential

Key Limitations:

- Potential for thermal impacts downstream
- Must be carefully designed to achieve low, non-erosive flow rates in the channel
- May re-suspend sediment
- May not be acceptable for some areas due to standing water in channels

PERFORMANCE STANDARD COMPLIANCE					
Water Quality			Stream Channel Protection	Overbank Flood Protection	Extreme Flood Protection
Treatment Volume		80% TSS Removal			
Level 1	Level 2				
0-18[1]	6-25[1]		▶		

✓ Suitable for this practice

▶ Provides partial benefits

1 Refer to Table 6.7.2

6.7.1 General Application

Grass channels are conveyance channels that are designed to provide some treatment of runoff, as well as to slow down runoff velocities for treatment in other structural controls. Grass channels are appropriate for a number of applications including treating runoff from paved roads and from other impervious areas.

Grass channels can provide a modest amount of runoff filtering and volume attenuation within the storm water conveyance system resulting in the delivery of less runoff and pollutants than a traditional system of curb and gutter, storm drain inlets and pipes. The performance of grass channels will vary depending on the underlying soil permeability as shown in **Table 6.7.3**. Grass channels, however, are not capable of providing the same storm water functions as water quality swales as they lack the storage volume associated with the engineered soil media. Their runoff reduction performance can be increased when compost amendments are added to the bottom of the swale (see Appendix E). Grass channels are a preferable alternative to both curb and gutter and storm drains as a storm water conveyance system, where development density, topography, and soils permit.

6.7.2 Planning and Physical Feasibility

Grass channels can be implemented on development sites where development density, topography, and soils are suitable. The linear nature of grass channels makes them well-suited to treat highway runoff, low and medium density residential road runoff, and small commercial parking areas or driveways. However, a water quality swale (Chapter 6, Section 5) will provide much greater runoff reduction and pollutant removal performance. The following criteria provided it **Table 6.7.1** shall be considered when evaluating the suitability of a grass channel/open channel for a development site.

Table 6.7.1. Grass Channel/Open Channel Constraints

Contributing Drainage Area	Land Uses	Hydraulic Capacity	Hydraulic Head Needed	Setbacks
5 acres max.	When used for conveyance and water quality treatment, apply only in linear configurations parallel to contributing impervious cover (roads/small parking areas). Well-suited for highway/low- and medium-density residential road runoff if adequate ROW exists.	Shall convey the 2-yr. and 10-yr. storms at non-erosive velocities and contain the 10-yr. storm within banks.	3' min.	10 ft. down-gradient from building foundation.50 ft. from septic system fields. 100 ft. from private wells.
Soils Requirement	Space Needed	Topography	Utility Requirement	Water Table Requirement
HSG C and D soils require compost amendments to improve performance. Infiltration rate > 0.5 inches per hour required if infiltration of small runoff flow is intended. Infiltration test required.	Incorporated into linear development applications utilizing footprint typically required for open section drainage feature. The footprint required may be greater than that of a typical conveyance, but the runoff reduction may reduce the footprint requirements for storm water management elsewhere.	<4% longitudinal slopes. Slopes <2% may eliminate need for check dams. <1% shall be monitored carefully during construction to ensure a continuous grade to avoid flat areas with pockets of standing water.	Utilities under GIP require double casing or other special protection or below channel invert. Local utility guidance shall also be followed.	2' of separation

The data listed below is necessary for the design of a grass channel/open channel and shall be included with the development plan. See Appendix B for more information on required elements for the development plan.

- Existing and proposed site, topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Water surface elevation of nearby water systems as well as the depth to seasonally high groundwater.
- Infiltration testing of native soils at proposed invert elevation.

6.7.3 Design Requirements

Grass channels must meet the minimum criteria outlined in **Table 6.7.2** to qualify for the indicated level of runoff reduction. Level 1 design (RR 0 to 18) is applicable on C and D soils. Level 2 design (RR 6 to 25) is applicable on A and B soils. The native soil's Hydrologic Soil Group (HSG) and use of compost amendments determines runoff reduction (Table 6.7.3).

Table 6.7.2. Grass Channel Design Guidance

Design Criteria
The bottom width of the channel shall be 2 to 8 feet wide.
The channel side-slopes should be 3H:1 V or flatter.
The maximum total contributing drainage area to any individual grass channel is 5 acres.
The longitudinal slope of the channel should be no greater than 4%.
Check dams may be used to increase residence time. Vegetated check dams have also been shown to increase volume reduction.
The maximum flow velocity of the channel must be less than 1 foot per second during a 1-inch storm event.
The dimensions of the channel should ensure that flow velocity is non-erosive during the 2-year and 10-year design storm events and the 10-year design flow is contained within the channel (minimum of 6 inches of freeboard).
The vegetation used should be hardy and able to withstand relatively high velocities as well as a range of moisture conditions from very wet to dry.

Figure 6.5.2. Example of Grass Channel along ROW

Table 6.7.3. Annual Runoff Volume Reduction Provided by Grass Channels[1]

Storm Water Function	Level 1 HSG Soils C and D		Level 2 HSG Soils A and B	
	No CA[2]	With CA	No CA[2]	With CA[3]
Annual Runoff Volume Reduction (RR)	10%	20%	20%	30%[3]

1 CSN (2008) and CWP (2007).
2 CA= Compost Amended Soils, see Appendix E.
3 Compost amendments are generally not applicable for A and B soils, although it may be advisable to incorporate them on mass-graded and/or excavated soils to maintain runoff reduction rates. In these cases, the 30% runoff reduction rate may be claimed, regardless of the pre-construction HSG.

Sizing of Grass Channels/Open Channels

Storm Water Quality

Unlike other storm water practices, grass channels are designed based on a peak rate of flow. Designers must demonstrate channel conveyance and treatment capacity in accordance with the following guidelines:

- The longitudinal slope of the channel should ideally be between 1% and 2% in order to avoid scour and short-circuiting within the channel. Longitudinal slopes up to 4% are acceptable; however, check dams will likely be required in order to meet the allowable maximum flow velocities.
- A minimum residence time of five minutes is required.
    - Hydraulic capacity should be verified using Manning's Equation or an accepted equivalent method, such as erodibility factors and vegetal retardance.
    - The flow depth for the peak treatment volume should be maintained at 3 inches or less.
    - Manning's "n" value for grass channels should be 0.2 for flow depths up to 4 inches, decreasing to 0.03 at a depth of 12 inches (which would apply to the 2-year and 10-year storms in an on-line application – NOVA, 2007; Haan et. al, 1994).
    - Peak Flow Rates for the 2-year and 10-year frequency storms must be non-erosive, and the 10-year peak flow rate must be contained within the channel banks (with a minimum of 6 inches of freeboard).
- Larger flows should be accommodated by the channel if dictated by the surrounding conditions. For instance, Birmingham requires site drainage to accommodate the 10-year design storm.
- Calculations for peak flow depth and velocity should reflect any increase in flow along the length of the channel, as appropriate. If a single flow is used, the flow at the outlet should be used.
- The minimum length may be achieved with multiple swale segments connected by culverts with energy dissipaters.

Table 6.7.4. Maximum Permissible Velocities for Grass Channels

Cover Type	Erosion Resistant Soils (ft./sec.)	Easily Eroded Soils (ft./sec.)
Bermuda grass	6	4.5
Kentucky bluegrass Tall fescue	5	3.8
Grass-legume mixture	4	3
Kentucky blue grass Tall fescue	3	2.3
Red fescue	2.5	1.9

Sources: Virginia E&S Control Handbook, 1992; Ree, 1949; Temple et al, 1987

Geometry and Site Layout

- Grass channels should generally be aligned adjacent to and the same length (minimum) as the contributing drainage area identified for treatment.
- Grass channels should be designed with a trapezoidal or parabolic cross section with relatively flat side slopes. A parabolic shape is preferred for aesthetic, maintenance, and hydraulic reasons.
- The bottom width of the channel should be between 2 to 8 feet wide. If a channel will be wider than 8 feet, the designer should incorporate benches, check dams, level spreaders, or multi-level cross sections to prevent braiding and erosion along the channel bottom. The bottom width is a dependent variable in the calculation of velocity based on Manning's equation. If a larger channel is needed, the use of a compound cross section is recommended.
- Grass channel side slopes should be no steeper than 3 H:1 V for ease of mowing and routine maintenance. Flatter slopes are encouraged, where adequate space is available, to aid in pre-treatment of sheet flows entering the channel.

Check Dams

Check dams may be used for pre-treatment to break up slopes and to increase the hydraulic residence time in the channel. Design requirements for check dams are as follows:

- Check dams should be spaced based on the channel slope, as needed to increase residence time, provide T_v storage volume, or any additional volume attenuation requirements. The ponded water at a downhill check dam should not touch the toe of the upstream check dam.
- The maximum desired check dam height is 12 inches (for maintenance purposes). The average ponding depth throughout the channel should be 12 inches.
- Armoring may be needed at the downstream toe of the check dam to prevent erosion.
- Check dams must be firmly anchored into the side-slopes to prevent outflanking; check dams must also be anchored into the channel bottom so as to prevent hydrostatic head from pushing out the underlying soils.
- Check dams must be designed with a center weir sized to pass the channel design storm peak flow (10-year storm event for man-made channels).
- The check dam should be designed so that it facilitates easy mowing.
- Each check dam should have a weep hole or similar drainage feature so it can dewater after storms.
- Options for check dams composition include: wood, concrete, stone, other non-erodible material, vegetated check dams, or check dams configured with elevated driveway culverts.
- Vegetated check dams have been shown to increase volume reduction and are encouraged where appropriate.
- Individual channel segments formed by check dams or driveways should generally be at least 25 to 40 feet in length.

Compost Soil Amendments

Soil compost amendments serve to increase the runoff reduction capability of a grass channel. The following design criteria apply when compost amendments are used:

- The compost-amended strip should extend over the length and width of the channel bottom, and the compost should be incorporated to a depth as outlined in Appendix E.
- The amended area will need to be rapidly stabilized with grass.
- Depending on the slope of the channel, it may be necessary to install a protective biodegradable geotextile fabric to protect the compost-amended soils. Care must be taken to consider the erosive characteristics of the amended soils when selecting an appropriate geotextile.
- For redevelopment or retrofit applications, the final elevation of the grass channel (following compost amendment) must be verified as meeting the original design hydraulic capacity.

Planting Grass Channels

Designers should choose grass species that can withstand both wet and dry periods as well as relatively high-velocity flows within the channel. For applications along roads and parking lots, salt tolerant species should be chosen. Taller and denser grasses are preferable, though the species of grass is less important than good stabilization.

Grass channels should be seeded at such a density to achieve a 90% turf cover after the second growing season. Performance has been shown to fall rapidly as vegetative cover falls below 80%. Grass channels should be seeded and not sodded. Seeding establishes deeper roots and sod may have muck soil that is not conducive to infiltration (Storey et. al., 2009). Grass channels should be protected by a biodegradable erosion control fabric to provide immediate stabilization of the channel bed and banks.

Grass Channel Material Specifications

The basic material specifications for grass channels are outlined in **Table 6.7.5** below.

Table 6.7.5. Grass Channel Materials Specifications

Component	Specification
Grass	A dense cover of water-tolerant, erosion-resistant grass. The selection of an appropriate species or mixture of species is based on several factors including climate, soil type, topography, and sun or shade tolerance. Grass species should have the following characteristics: a deep root system to resist scouring; a high stem density with well-branched top growth; water-tolerance; resistance to being flattened by runoff; an ability to recover growth following inundation; and, if receiving runoff from roadways, salt-tolerance.
Check Dams	• Check dams should be constructed of a non-erosive material such as wood, gabions, riprap, or concrete, or be vegetated. All check dams should be underlain with filter fabric conforming to local design standards. • Wood used for check dams should consist of pressure treated logs or timbers, or water-resistant tree species such as cedar, hemlock, swamp oak, or locust. • Computation of check dam material is necessary based on the surface area and depth used in the design computations. (see http://vwrrc.vt.edu/swc/NonPBMPSpecsMarch11/Introduction_App%20A_Earthen%20Embankments_SCraftonRev_03012011.pdf .)

Component	Specification
Diaphragm	Pea gravel used to construct pre-treatment diaphragms should consist of washed, open-graded, course aggregate between 3 and 10 mm in diameter and must conform to local design standards.
Erosion Control Fabric	Where flow velocities dictate, biodegradable erosion control netting or mats that are durable enough to last at least two growing seasons must be used.
Filter Fabric (check dams)	Needled, non-woven, polypropylene geotextile meeting the following specifications: Grab Tensile Strength (ASTM D4632): > 120 lbs Mullen Burst Strength (ASTM D3786): > 225 lbs./sq. in. Flow Rate (ASTM D4491): > 125 gpm/sq. ft. Apparent Opening Size (ASTM D4751): US #70 or #80 sieve

6.7.4 Construction, Protection, and Maintenance Requirements

All GIPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all GIPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For City policies, additional guidance, and forms pertaining to GIP protection, inspection, and maintenance requirements, see Appendix B of this manual.

Requirements During Construction

- Construction equipment shall be restricted from the grass channel/open channel area to prevent compaction of the native soils.
- A dense and vigorous vegetative cover, or other effective soil stabilization practice, shall be established over the contributing pervious drainage areas before storm water can be accepted into the grass channel/open channel. This will prevent sediment from building up in the GIP.
- Areas where GIPs will be located shall be readily identifiable and protected from unwanted encroachments during construction, both on development plans and at the construction site. Physical protection measures can include, but are not limited to, orange fencing, wood or chain link fencing, and signage. For infiltration-based practices, protection of GIP locations during construction of a land development will ensure that native soils that surround (or are within) the storm water treatment area will remain un-compacted and, therefore, continue to meet the design parameters that were specified in the approved development plan. For other practices, such as extended detention ponds, protection of GIP locations can reduce the soil compaction that typically occurs during construction, which often leads to poor soil conditions for plant growth once the GIP shall be permanently stabilized. Regardless, a lack of GIP protection will most certainly reduce or destroy the storm water functionality of the GIP once it is installed, often leading to costly corrective actions required by the City.

Protection Requirements

- Provide signage for the GIP.
    - Allows for easy identification and location of the GIP.
    - Serves as a general education tool, making those responsible for property, landscape or GIP maintenance, and the general public aware of the water quality features of the GIP and to avoid encroachment.
    - Consider using natural fencing such as graduated vegetation sizes and densities, dense shrub fencing, rocks, or other landscape features placed in a manner that discourages foot, equipment and vehicle traffic in the storm water treatment area.

- Design the layout of the grass channel/open channel such that maintenance access can be achieved without the need for vehicles or equipment in the storm water treatment area.
- Provide clearly marked, easily accessible, and well-maintained driveways, sidewalks, and pedestrian pathways that lead vehicles, equipment, and foot traffic around the storm water treatment areas.

Inspection Requirements

- Inspect the areas where storm water flows into or out of the grass channel/open channel for clogging or sediment buildup.
- Inspect vegetation to ensure it meets landscaping and vegetation specifications. Replace if necessary.
- Inspect the property that drains to the grass channel/open channel for erosion, exposed soil, or stockpiles of other potential pollutants.

Maintenance Requirements

- Maintain grass height of 3 to 4 inches.
- Remove sediment build up in channel when it accumulates to 25% or original total channel volume.
- Perform weeding and trash removal as needed to maintain appearance.
- Inspect vegetation to evaluate health, replace if necessary.
- Keep inlets clear of debris to prevent clogging, clear if necessary.
- Inspect grass channel/open channel area for sediment build up, erosion, vegetative health/conditions, etc. perform appropriate maintenance as necessary.

References

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6.8 Sheet Flow

Figure 6.8.1. Level Spreader for Dispersing Water over Sheet Flow Area

DEVELOPMENT ATTRIBUTES

Construction Cost	LOW
Operation and Maintenance Cost	LOW
Ground-Level Encroachment	MODERATE
Building Footprint Enhancement	MODERATE
Triple Bottom-Line Benefits	MODERATE

Intrinsic GIP

Description:

Impervious areas are disconnected, and runoff is routed over a level spreader to sheet flow over adjacent vegetated areas. This slows runoff velocities, promotes infiltration, and allows sediment and attached pollutants to settle and/or be filtered by the vegetation.

Variations:

- Disconnection to vegetated filter strips
- Disconnection to conserved open space

Key Advantages:

- Cost effective
- Wildlife habitat potential
- High community acceptance

Key Limitations:

- Small drainage area
- Sheet flow shall be maintained to achieve design goals
- Often requires additional GIPs to achieve runoff reduction goals

PERFORMANCE STANDARD COMPLIANCE					
Water Quality			Stream Channel Protection	Overbank Flood Protection	Extreme Flood Protection
Treatment Volume		80% TSS Removal			
Level 1	Level 2				
41 RR Credit[1] 44 RR Credit[2]	73 RR Credit[1] 50 RR Credit[2]	▶	▶	▶	▶

✓ Suitable for this practice

▶ Provides partial benefits

1 Sheet flow directed to pervious area.

2 Sheet flow directed to filter strip.

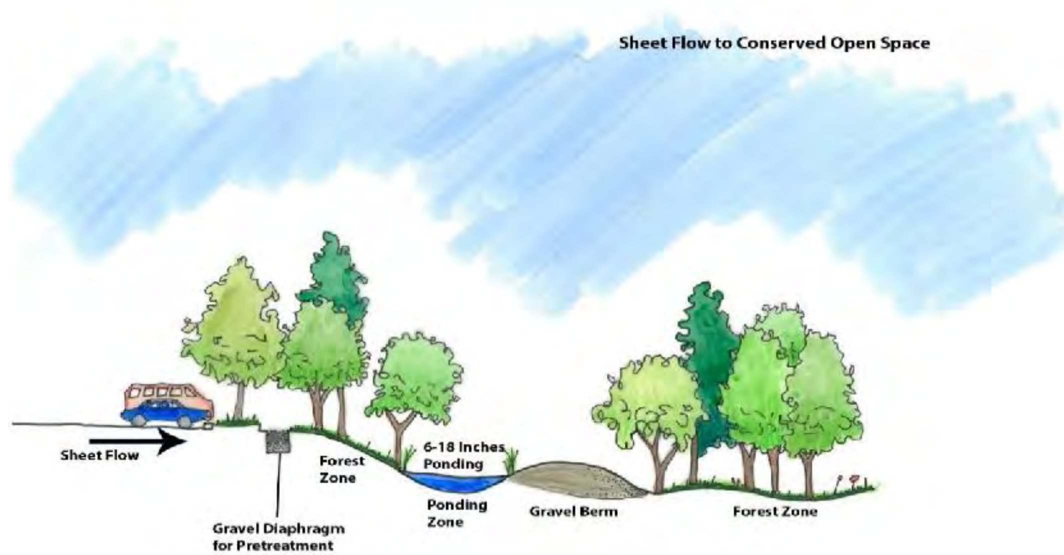
6.8.1 General Application

Filter strips are vegetated areas that treat sheet flow delivered from adjacent impervious areas by slowing runoff velocities and allowing sediment and attached pollutants to settle and/or be filtered by the vegetation. The two design variants of filter strips are (1) conserved open space and (2) vegetated filter strips. The design, installation, and management of these design variants are quite different, as outlined in this specification. In both instances, storm water shall enter the filter strip or conserved open space as sheet flow. If the inflow is from a pipe or channel, an engineered level spreader shall be designed in accordance with the criteria contained herein to convert the concentrated flow to sheet flow.

Conserved Open Space. Designers may apply a runoff reduction credit to any impervious area that is hydrologically connected and effectively treated by a protected conserved open space that meets the following eligibility criteria:

- No major disturbance may occur within the conserved open space during or after construction (i.e., no clearing or grading is allowed except temporary disturbances associated with incidental utility construction, restoration operations, or management of nuisance vegetation). The conserved open space area shall not be stripped of topsoil. Some light grading may be needed at the boundary using tracked vehicles to prevent compaction.
- The limits of disturbance shall be clearly shown on all construction drawings and protected by acceptable signage and erosion control measures.
- A long-term vegetation management plan shall be prepared to maintain the conserved open space in a natural vegetative condition. Generally, conserved open space management plans do not allow any active management. However, a specific plan shall be developed to manage the unintended consequences of passive recreation, control invasive species, provide for tree and understory maintenance, etc.
- The conserved open space shall be protected by a perpetual easement or deed restriction that assigns the responsible party to ensure that no future development, disturbance, or clearing may occur within the area.
- The practice does *not* apply to jurisdictional wetlands that are sensitive to increased inputs of storm water runoff.

Vegetated Filter Strips. Vegetated filter strips are best suited to treat runoff from small segments of impervious cover (usually less than 5,000 sq. ft) adjacent to road shoulders, small parking lots, and rooftops. Vegetated filter strips may also be used as pretreatment for another GIP such as a dry swale, bioretention, or infiltration areas. If sufficient pervious area is available at the site, larger areas of impervious cover can be treated by vegetated filter strips, using an engineered level spreader to recreate sheet flow.



6.8.2 Planning and Physical Feasibility

Conserved open space and vegetated filter strips can be used in a variety of situations. The following criteria provided it **Table 6.8.1** shall be considered when evaluating the suitability of a sheet flow area for a development site.

Table 6.8.1. Sheet Flow Area Constraints

Flow Path	Hotspot Land Uses	Soils Requirement	Topography	Utility Requirement
75 ft. max. flow length for impervious surfaces and 150 ft. max. flow length for pervious surfaces unless engineered level spreader used.	Not allowed for vegetated filter strips.	RR depends on HSG and whether soils receive compost amendments. Infiltration test required.	6% max. slope for both contributing area and conserved open space/ vegetated filter strip unless engineered level spreader used.	Consider clearance for all utilities. Underground pipes and conduits that cross the sheet flow areas are acceptable.

The data listed below is necessary for the design of a sheet flow area and shall be included with the development plan. See Appendix B for more information on required elements for the development plan.

- Existing and proposed site, topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Infiltration testing of native soils at proposed elevation of bottom of sheet flow area.

6.8.3 Design Requirements

Design criteria for sheet flow are detailed in **Table 6.8.2**.

Table 6.8.2. Sheet Flow Design Criteria

Design Issue	Conserved Open Space	Vegetated Filter Strip
Vegetative and Soil Cover (Appendices C and E)	Undisturbed soils and native vegetation	Amended soils and dense turf cover or landscaped with herbaceous cover, shrubs, and trees
Overall Slope and Width (perpendicular to the flow)	0.5% to 3% Slope – Minimum 35 ft. width 3% to 6% Slope – Minimum 50 ft. width The first 10 ft. of filter shall be 2% or less in all cases [2]	1%[1] to 4% Slope – Minimum 35 ft. width 4% to 6% Slope – Minimum 50 ft. width The first 10 ft. of filter shall be 2% or less in all cases [2]
Sheet Flow	Maximum flow length of 150 ft. from adjacent pervious areas; Maximum flow length of 75 ft. from adjacent impervious areas	
Concentrated Flow	Length of ELS[6] lip = 13 lin. ft. per each 1 cfs of inflow if area has 90% Cover[3] Length = 40 lin. ft. per 1 cfs for[4] forested or re-forested areas (ELS[6] length = 13 lin. ft. min; 130 lin. ft. max.)	Length of ELS[6] lip = 13 lin. ft. per each 1 cfs of inflow (13 lin. ft. min; 130 lin. ft. max.)
Construction Stage	Located outside the limits of disturbance and protected by soil erosion and sediment controls	Prevent soil compaction by heavy equipment
Typical Applications	Adjacent to stream or wetland buffer or forest conservation area	Treat small areas of Impervious Cover (e.g., 5,000 sq. ft.) close to source
Compost Amendments	No	Yes (B, C, and D soils)[5]

Design Issue	Conserved Open Space	Vegetated Filter Strip
Boundary Spreader	GD[6] at top of filter	GD[6] at top of filter PB[6] at toe of filter

1 A minimum of 1% is required to ensure positive drainage.
2 For Conservation Areas with a varying slope, a pro-rated length may be computed only if the first 10 ft. is 2% or less.
3 Vegetative Cover is described below.
4 Where the conserved open space is a mixture of native grasses, herbaceous cover, and forest (or re-forested area), the length of the ELS6 lip can be established by computing a weighted average of the lengths required for each vegetation type.
5 Birmingham may waive the requirement for compost amended soils for filter strips on B soils if the designer can provide verification of the adequacy of the on-site soil type, texture, and profile to function as a filter strip, and the area designated for the filter strip will not be disturbed during construction.
6 ELS = Engineered Level Spreader; GD = Gravel Diaphragm; PB = Permeable Berm.

Conserved open space and vegetated filter strips do not have two levels of design. Instead, each shall meet the appropriate minimum criteria outlined in Table 6.8.2 and below to qualify for the indicated level of runoff reduction. In addition, designers shall conduct a site reconnaissance prior to design to confirm topography and soil conditions. With proper design and maintenance, these practices can provide relatively high runoff reduction as shown in **Table 6.8.3**.

Table 6.8.3. Annual Runoff Volume Reduction Provided by Sheet Flow

Storm Water Function	Conservation Area		Vegetated Filter Strip	
	HSG Soils A and B	HSG Soils C and D	HSG Soils A	HSG Soils B [1], C and D
	Assume no CA[2] in Conservation Area		No CA[3]	With CA[2]
Annual Runoff Vol. Reduction (RR)	73%	41%	50%	44%

1 CSN (2008); CWP (2007)
2 CA = Compost Amended Soils
3 Compost amendments are generally not applicable for undisturbed A soils, although it may be advisable to incorporate them on mass-graded A or B soils and/or filter strips on B soils, to maintain runoff reduction rates.

Compost Soil Amendments

Compost soil amendments will enhance the runoff reduction capability of a vegetated filter strip when located on hydrologic soil groups B, C, and D subject to the following design requirements:

- ❖ The compost amendments shall extend over the full length and width of the filter strip.
- ❖ The amount of approved compost material and the depth to which it shall be incorporated is outlined in Appendix E.
- ❖ The amended area will be raked to achieve the most level slope possible without using heavy construction equipment, and it will be stabilized rapidly with perennial grass and/or herbaceous species.
- ❖ If slopes exceed 3%, a protective biodegradable fabric or matting shall be installed to stabilize the site prior to runoff discharge.
- ❖ Compost amendments shall not be incorporated until the gravel diaphragm and/or engineered level spreader are installed.
- ❖ Birmingham may waive the requirement for compost amendments on HSG-B soils to receive credit as a filter strip if (1) the designer can provide verification of the adequacy of the on-site soil type, texture, and profile to function as a filter strip, and (2) the area designated for the filter strip will not be disturbed during construction.

Planting and Vegetation Management

No grading or clearing of native vegetation is allowed within the conserved open space.

At some sites, the conserved open space may be in turf or meadow cover or overrun with invasive plants and vines. In these situations, a landscape architect shall prepare a reforestation plan for the conserved open space utilizing the reforestation specifications as described in the Reforestation GIP (see Chapter 6, Section 9), with any credits and associated plans receiving approval by Birmingham.

Vegetated filter strips shall be planted at such a density to achieve a 90% grass/herbaceous cover after the second growing season. Performance has been shown to fall rapidly as vegetative cover falls below 80%. Filter strips shall be seeded, not sodded, whenever possible. Seeding establishes deeper roots, and sod may have muck soil that is not conducive to infiltration (Storey et. al., 2009). The filter strip vegetation may consist of turf grasses, meadow grasses, other herbaceous plants, shrubs, and trees, as long as the primary goal of at least 90% coverage with grasses and/or other herbaceous plants is achieved. Designers shall choose vegetation that stabilizes the soil and is salt tolerant. Vegetation at the toe of the filter, where temporary ponding may occur behind the permeable berm, shall be able to withstand both wet and dry periods. The planting areas can be divided into zones to account for differences in inundation and slope.

Diaphragms, Berms, and Level Spreaders

A pea gravel diaphragm at the top of the slope is required for both conserved open space and vegetated filter strips that receive sheet flow. The pea gravel diaphragm is created by excavating a 2-foot wide and 1-foot deep trench that runs on the same contour at the top of the filter strip. The diaphragm serves two purposes. First, it acts as a pre-treatment device, settling out sediment particles before they reach the practice. Second, it acts as a level spreader, maintaining sheet flow as runoff flows over the filter strip. Typical details are located in Appendix F.

- The flow shall travel over the impervious area and to the practice as sheet flow and then drop at least 3 inches onto the gravel diaphragm. The drop helps to prevent runoff from running laterally along the pavement edge, where grit and debris tend to build up (thus allowing by-pass of the filter strip).
- A layer of filter fabric shall be placed between the gravel and the underlying soil trench.
- If the contributing drainage area is steep (6% slope or greater), then larger stone (clean bank-run gravel that meets ALDOT #57 grade) shall be used in the diaphragm.

Vegetated filter strips shall be designed with a permeable berm at the toe of the filter strip to create a shallow ponding area. Runoff ponds behind the berm and gradually flows through outlet pipes in the berm or through a gravel lens in the berm with a perforated pipe. During larger storms, runoff may overtop the berm (Cappiella et al., 2006). The permeable berm shall have the following properties:

- A wide and shallow trench, 6 to 12 inches deep, shall be excavated at the upstream toe of the berm, parallel with the contours.
- Media for the berm shall consist of 40% excavated soil, 40% sand, and 20% pea gravel.
- The berm 6 to 12 inches high shall be located down gradient of the excavated depression and shall have gentle side slopes to promote easy mowing (Cappiella et al., 2006).
- Stone may be needed to armor the top of berm to handle extreme storm events.
- A permeable berm is not needed when vegetated filter strips are used as pretreatment to another GIP.

The design of engineered level spreaders shall conform to the following design criteria based on recommendations of Hathaway and Hunt (2006) to ensure non-erosive sheet flow into the vegetated area.

An alternative approach involves pipe or channels discharging at the landward edge of a floodplain. The entire flow is directed through a stilling basin energy dissipater and then a level spreader such that the entire design storm for the conveyance system (typically a 10-year frequency storm) is discharged as sheet flow through the floodplain.

Key design elements of the engineered level spreader include the following:

- High flow bypass provides safe passage for larger design storms through the filter strip. The bypass channel shall accommodate all peak flows greater than the water quality design flow.
- A forebay shall have a maximum depth of 3 feet and gradually transition to a depth of 1 foot at the level spreader lip. The forebay is sized such that the surface area is 0.2% of the contributing impervious area. (A forebay is not necessary if the concentrated flow is from the outlet of an extended detention basin or similar practice.)
- The length of the level spreader shall be determined by the type of filter area and the design flow:
    - 13 feet of level spreader length per every 1 cubic foot per second (cfs) of inflow for discharges to a vegetated filter strip or conserved open space consisting of native grasses or thick ground cover.
    - 40 feet of level spreader length per every 1 cfs of inflow when the spreader discharges to a conserved open space consisting of forested or reforested area (Hathaway and Hunt, 2006).
    - Where the conserved open space is a mix of grass and forest (or re-forested), establish the level spreader length by computing a weighted average of the lengths required for each vegetation type.
    - The minimum level spreader length is 13 feet, and the maximum is 130 feet.
- For the purposes of determining the level spreader length, the peak discharge shall be determined using the Rational Equation with an intensity of 1-inch/hour.
- The level spreader lip shall be concrete, wood, or pre-fabricated metal, with a well-anchored footer, or other accepted rigid, non-erodible material.
- The ends of the level spreader section shall be tied back into the slope to avoid scouring around the ends of the level spreader; otherwise, short-circuiting of the facility could create erosion.
- The width of the level spreader channel on the up-stream side of the level lip shall be three times the diameter of the inflow pipe, and the depth shall be 9 inches or one-half the culvert diameter, whichever is greater.
- The level spreader shall be placed 3 to 6 inches above the downstream natural grade elevation to avoid turf buildup. To prevent grade drops that re-concentrate the flows, a 3-foot long section of coarse aggregate, underlain by filter fabric, shall be installed just below the spreader to transition from the level spreader to natural grade.

Vegetated receiving areas down-gradient from the level spreader shall be able to withstand the force of the flow coming over the lip of the device. It may be necessary to stabilize this area with temporary or permanent materials in accordance with the calculated velocity (on-line system peak, or diverted off-line peak) and material specifications, along with seeding and stabilization in conformance with the Alabama Handbook for Erosion Control, Sediment Control, and Stormwater Management on Construction Sites and Urban Areas.

Filter Design Material Specifications

Table 6.8.4 describes materials specifications for the primary treatment within filter strips.

Table 6.8.4. Vegetated Filter Strip Materials Specifications

Material	Specification	Quantity
Gravel Diaphragm	Pea Gravel (#8 or ASTM equivalent) or where steep (6% +) use clean bank-run #57 stone or ASTM equivalent (1-inch maximum).	Diaphragm shall be 2 feet wide, 1 foot deep, and at least 3 inches below the edge of pavement.
Permeable Berm	40% excavated soil, 40% sand, and 20% pea gravel to serve as the media for the berm.	
Geotextile	Needled, non-woven, polypropylene geotextile meeting the following specifications: Grab Tensile Strength (ASTM D4632): > 120 lbs. Mullen Burst Strength (ASTM D3786): > 225 lbs./sq. in. Flow Rate (ASTM D4491): > 125 gpm/sq. ft. Apparent Opening Size (ASTM D4751): US #70 or #80 sieve	
Engineered Level Spreader	Level spreader lip shall be concrete, metal, timber, or other rigid material; Reinforced channel on upstream of lip. See Hathaway and Hunt (2006)	
Erosion Control Fabric or Matting	Where flow velocities dictate, use woven biodegradable erosion control fabric or mats that are durable enough to last at least 2 growing seasons.	
Topsoil	If existing topsoil is inadequate to support dense turf growth, imported top soil (loamy sand or sandy loam texture), with less than 5% clay content, corrected pH at 6 to 7, a soluble salt content not exceeding 500 ppm, and an organic matter content of at least 2% shall be used. Topsoil shall be uniformly distributed and lightly compacted to a minimum depth of 6 to 8 inches.	
Compost	Compost shall be derived from plant material and provided by a member of the U.S. Composting Seal of Testing Assurance (STA) program, as outlined in Appendix E.	

6.8.4 Construction, Protection, and Maintenance Requirements

All GIPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all GIPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For City policies, additional guidance, and forms pertaining to GIP protection, inspection, and maintenance requirements, see Appendix B of this manual.

Requirements During Construction

- Construction equipment shall be restricted from the sheet flow area to prevent compaction of the native soils.
- A dense and vigorous vegetative cover, or other effective soil stabilization practice, shall be established over the contributing pervious drainage areas before storm water can be accepted into the sheet flow area. This will prevent sediment from clogging the pores in the planting media.
- Areas where GIPs will be located shall be readily identifiable and protected from unwanted encroachments during construction, both on development plans and at the construction site. Physical protection measures can include, but are not limited to, orange fencing, wood or chain link fencing, and signage. For infiltration-based practices, protection of GIP locations during construction of a land development will ensure that native soils that surround (or are within) the storm water treatment area will remain un-compacted and, therefore, continue to meet the design parameters that were specified in the approved development plan. For other practices, such as extended detention ponds, protection of GIP locations can reduce the soil compaction that typically occurs during construction, which often leads to poor soil conditions for plant growth once the GIP shall be permanently stabilized. Regardless, a lack of GIP protection will most certainly reduce or destroy the storm water functionality of the GIP once it is installed, often leading to costly corrective actions required by the City.

Protection Requirements

- Provide signage for the GIP.
    - Allows for easy identification and location of the GIP.
    - Serves as a general education tool, making those responsible for property, landscape or GIP maintenance, and the general public aware of the water quality features of the GIP and to avoid encroachment.
    - Consider using natural fencing such as graduated vegetation sizes and densities, dense shrub fencing, rocks, or other landscape features placed in a manner that discourages foot, equipment, and vehicle traffic in the storm water treatment area.
- Design the layout of the sheet flow area such that maintenance access can be achieved without the need for vehicles or equipment in the storm water treatment area.
- Provide clearly marked, easily accessible, and well-maintained driveways, sidewalks, and pedestrian pathways that lead vehicles, equipment, and foot traffic around the storm water treatment areas.

Inspection Requirements

- Inspect to ensure flows through the filter strip do not short-circuit the overflow control system.
- Inspect for debris and sediment build-up.
- Inspect for signs that foot or vehicular traffic are compromising the gravel diaphragm.
- Inspect for scour and erosion.
- Inspect health and density of vegetation. Vegetation cover shall exceed 90% in the boundary zone or grass filter.

Maintenance Requirements

- Perform weeding and trash removal as needed to maintain appearance.
- Mowing shall be conducted regularly to prevent woody vegetation.
- Inspect vegetation to evaluate health, replace if necessary.
- Keep forebays, flow splitters, gravel diaphragms, and overflow control system clear of debris and sediment to prevent clogging, clear if necessary.

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6.9 Reforestation

Intrinsic GIP

Figure 6.9.1. Example of Reforestation

DEVELOPMENT ATTRIBUTES

Construction Cost	LOW
Operation and Maintenance Cost	LOW
Ground-Level Encroachment	HIGH
Building Footprint Enhancement	MODERATE
Triple Bottom-Line Benefits	MODERATE

Description:

Reforestation refers to trees planted in groups in urban areas such as: parking lots, right of ways (ROW), parks, schools, public lands, vacant land, and neighborhood open spaces to provide shade and storm water retention and to add aesthetic value.

Key Advantages:

- Reduces effective impervious cover
- Reduces storm water runoff
- Provides aesthetic value
- Provides rainfall interception
- Shade provides cooling and energy savings
- Habitat creation
- Provides pollutant removal
- Provides flow attenuation

Key Limitations:

- Poor quality urban soils may require soil amendments or remediation
- Long-term maintenance is required for high tree survival rates
- Must be implemented over large areas to see significant reduction in storm water runoff
- Time required for trees to mature
- Poor soils, improper planting methods, conflicts with paved areas and utilities, inputs from road salt, lack of water, or disease can lead to low survival rate

PERFORMANCE STANDARD COMPLIANCE					
Water Quality			Stream Channel Protection	Overbank Flood Protection	Extreme Flood Protection
Treatment Volume		80% TSS Removal			
w/o compost amended soils	w/ compost amended soils				
Calculate by R_v value[1]	Calculate by R_v value[2]	▶	▶	▶	▶

✓ Suitable for this practice

▶ Provides partial benefits

1 RR is expressed as Rv value for reforested area. 0.18 for Hydrologic Soil Group (HSG) D soils, 0.16 for C soils, 0.14 for B soils, and 0.10 for A soils (w/o compost amended soils).

2 RR is expressed as Rv value for reforested area. 0.06 for HSG D soils, 0.05 for C soils, 0.04 for B soils, and 0.02 for A soils (w/ compost amended soils).

6.9.1 General Application

Site reforestation involves planting trees at a development site with the explicit goal of establishing a mature forest canopy that will intercept rainfall, increase evapotranspiration rates, and enhance soil infiltration rates.

Figure 6.9.2. Example of Forestation along a Walkway

6.9.2 Planning and Physical Feasibility

Trees are often one of the most economical storm water GIPs that can be introduced into an urban right-of-way (ROW). Tree canopies intercept rainfall before it becomes storm water and the tree boxes into which trees are planted can be used to capture and treat runoff. Trees also reduce the urban heat island effect, improve the urban aesthetic, and improve air quality. Data and modeling show that urban trees can remove over 50% of the moisture in the soil beneath their canopy. Refer to Appendix C for native tree species.

Tree plantings within the ROW must receive approval from Public Works. Vacant residential lots also provide reforestation opportunities. These lots can become an urban forest and an amenity to a neighborhood. Vegetation management plans must account for Health Department codes regarding overgrown lots and safety concerns of the residents. The following criteria provided in **Table 6.9.1** shall be considered when evaluating the suitability of reforestation for a development site.

Table 6.9.1. Reforestation Constraints

Overhead Wires	Sidewalks and Streets	Space Needed	Utility Requirement	Vegetation Management
The planting plan shall avoid placing trees under overhead utilities.	The area between curb and sidewalk and a 10 ft wide buffer adjacent to the sidewalk (away from the street) shall be kept mowed and clear.	5,000 sq ft min.	Alabama 811 shall be contacted prior to submission of planting plan to ensure that no utilities will be impacted by the tree planting.	While trees are being established, mowing is permitted between trees. Eventually, canopy should shade out grass. Vegetation management plans should consider if residents would prefer the site mowed in perpetuity.

The data listed below is necessary for the design of reforestation area and shall be included with the development plan. See Appendix B for more information on required elements for the development plan.

- Existing and proposed site, topographic and location maps, and field reviews.
- Document the condition of the reforested/revegetated area before development for comparison during and after the completion of the site reforestation/revegetation process.
- Infiltration testing and soil amendment information.

6.9.3 Design Requirements

Reforestation relies partially on underlying soils for infiltration. Therefore, RR values depend on hydrologic soil group (HSG) of native or amended soil. R_v values for HSGs are included in **Table 6.9.2**   Design criteria for urban bioretention are detailed in **Table 6.9.3**. The runoff reduction impact of the reforestation GIP is not calculated using an RR credit. It will be expressed as a Rv value for the reforested area based on the soil's HSG.

Table 6.9.2. Reforestation Rv Value

HSG Soil Group w/o Compost Amended Soil				HSG Soil Group w/ Compost Amended Soil			
A	B	C	D	A	B	C	D
0.10	0.14	0.16	0.18	0.02	0.04	0.05	0.06
Impervious area may be routed to the reforestation area following the guidance and applying the RR Credits detailed in Chapter 6, Section 8 under sheet flow.							

Table 6.9.3. Reforestation Design Criteria

Item	Specifications
Area	Minimum contiguous area of 5,000 sq. ft.
Tree Type	No more than 20% of any single tree species. Consider composition of local forests in planting design. 2/3 of trees must be large canopy. See the USGS land fire map (http://landfire.cr.usgs.gov/viewer/) for delineation of forest type and Appendix C for native tree species.
Density	• 300 large canopy trees – species that normally achieve an overall height at maturity of thirty feet or more per acre • 10 shrubs substitute for 1 large canopy tree • 2 small canopy trees substitute for 1 large canopy tree Note: Adjustments to densities may be possible with Birmingham approval.
Canopy Rate	Achieve 75% forest canopy within first 10 years
Size	Tree - Minimum tree size 6-8 ft in height Shrub – 18-24 inches or 3-gallon size
Ground Cover	Entire area shall be covered with 2-4 inches of organic mulch or a native seed mix

Runoff Reduction Calculations

Reforestation involves using soil types currently on a site, with or without soil amendments. Current soil shall be preserved from compaction and disturbance during construction and should be clearly identified on all construction drawings and EPSC plans. Trees should be planted following tree selection criteria in Appendix C.

If using soil amendments, guidance is in Chapter 6, Section 2. This area is then treated as original forested area for calculation purposes. Forested R_v factors are shown in Table 6.9.2.

Once the forest area R_V is determined, continue through the design process with weighted R_V calculations (Chapter 4).

Reforestation areas are eligible under the following qualifying conditions:

- The minimum contiguous area of reforestation must be greater than 5,000 square feet, with no more than 20% of the area in any single tree species. The basic density of plantings is 300 large canopy trees per acre, approximately 12 feet on center. When shrubs are substituted for trees, there must be 10 shrubs per one large canopy tree. Two small canopy trees, such as dogwoods or red buds, may be substituted for one large canopy tree. Adjustments can be made to these densities for areas of urban reforestation with the approval of Birmingham. Reforestation shall consider the composition of area forests, and two thirds of selected trees must be large canopy. Reforestation methods shall achieve 75% forest canopy within ten years.
- The minimum size requirement for reforestation is saplings 6-8 feet in height. The minimum size requirement for shrubs is 18-24 inches or 3-gallon size. In addition, the entire reforestation shall be covered with 2-4 inches of organic mulch or with a native seed mix to help retain moisture and provide a beneficial environment for the reforestation.
- A long-term vegetation management plan must be prepared and filed with Birmingham to demonstrate the ability to maintain the reforestation area in an appropriate forest canopy condition. The plan shall include a scale drawing showing the area to be planted, along with a plant list which includes species, size, number, and packaging. In addition, the reforestation area shall be clearly identified on all construction drawings and Soil Erosion and Sediment Control (SESC) plans during construction.
- The reforestation area must be protected by a perpetual storm water easement or deed restriction which stipulates that no future development or disturbance may occur within the area.
- The planting plan must be approved by Birmingham including any special site preparation needs.
- The construction contract shall contain a care and replacement warranty extending at least two growing seasons to ensure adequate growth and survival of the plant community.
- The final size of the trees shall be considered when designing the planting plan. Alabama 811 must be contacted prior to the submission of the planting plan to ensure that no utilities will be impacted by the tree planting. The planting plan must also avoid placing trees under overhead utilities.

6.9.4 Construction, Protection, and Maintenance Requirements

All GIPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all GIPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For City policies, additional guidance, and forms pertaining to GIP protection, inspection, and maintenance requirements, see Appendix B of this manual.

Requirements During Construction

- Construction equipment shall be restricted from reforestation area to prevent compaction of the native soils.
- Areas where GIPs will be located shall be readily identifiable and protected from unwanted encroachments during construction, both on development plans and at the construction site. Physical protection measures can include, but are not limited to, orange fencing, wood or chain link fencing, and signage.

Protection Requirements

- Provide signage for the GIP.
  - Allows for easy identification and location of the GIP.
  - Serves as a general education tool, making those responsible for property, landscape or GIP maintenance, and the general public aware of the water quality features of the GIP and to avoid encroachment.
- Maintenance staff shall be trained on the proper maintenance of reforested/revegetated area and the importance of avoiding the use of heavy equipment in the GIP.

Inspection Requirements

- Monitor vegetation for at least three growing seasons to ensure growth and survival.

Maintenance Requirements

- Designate the area as a conservation area and permanently protect through a legally enforceable conservation instrument (e.g., conservation easement, deed restriction).
- Inspect area for invasive species, sediment build up, erosion, vegetative health/conditions, etc. and perform appropriate maintenance as necessary.

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6.10 Green Roof

Figure 6.10.1. Vestavia Hills Public Library Green Roof in Birmingham, AL

DEVELOPMENT ATTRIBUTES

Construction Cost	HIGH
Operation and Maintenance Cost	MODERATE
Ground-Level Encroachment	LOW
Building Footprint Enhancement	LOW
Triple Bottom-Line Benefits	HIGH

Intrinsic GIP

80% TSS Removal

Description:

A green roof is a layer of vegetation installed on top of a conventional flat or slightly sloped roof. It consists of waterproofing material, root permeable filter fabric, growing media, and specially selected plants.

Variations:

- Extensive green roofs have a thin layer of growing medium and are usually composed of sedums.
- Intensive green roofs have a thicker layer of growing medium and contain shrubs, trees, and other vegetation.

Key Advantages:

- Runoff volume reduction
- Provides flow attenuation
- Extends the life of a conventional roof by up to 20 years
- Provides increased insulation and energy savings
- Reduces air pollution
- Provides habitat for wildlife
- Increases aesthetic value
- Provides sound insulation
- Provides water quality treatment
- Reduces urban heat island effect

Key Limitations:

- Cost may be greater than a conventional roof, and feasibility is limited by load-bearing capacity of roof
- Must obtain necessary permits and comply with local building codes
- Requires more maintenance than a conventional roof
- May require irrigation

PERFORMANCE STANDARD COMPLIANCE					
Water Quality			Stream Channel Protection	Overbank Flood Protection	Extreme Flood Protection
Treatment Volume		80% TSS Removal			
Level 1	Level 2				
77 RR Credit	88 RR Credit	✓	▶	▶	▶

✓ Suitable for this practice

▶ Provides partial benefits

6.10.1 General Application

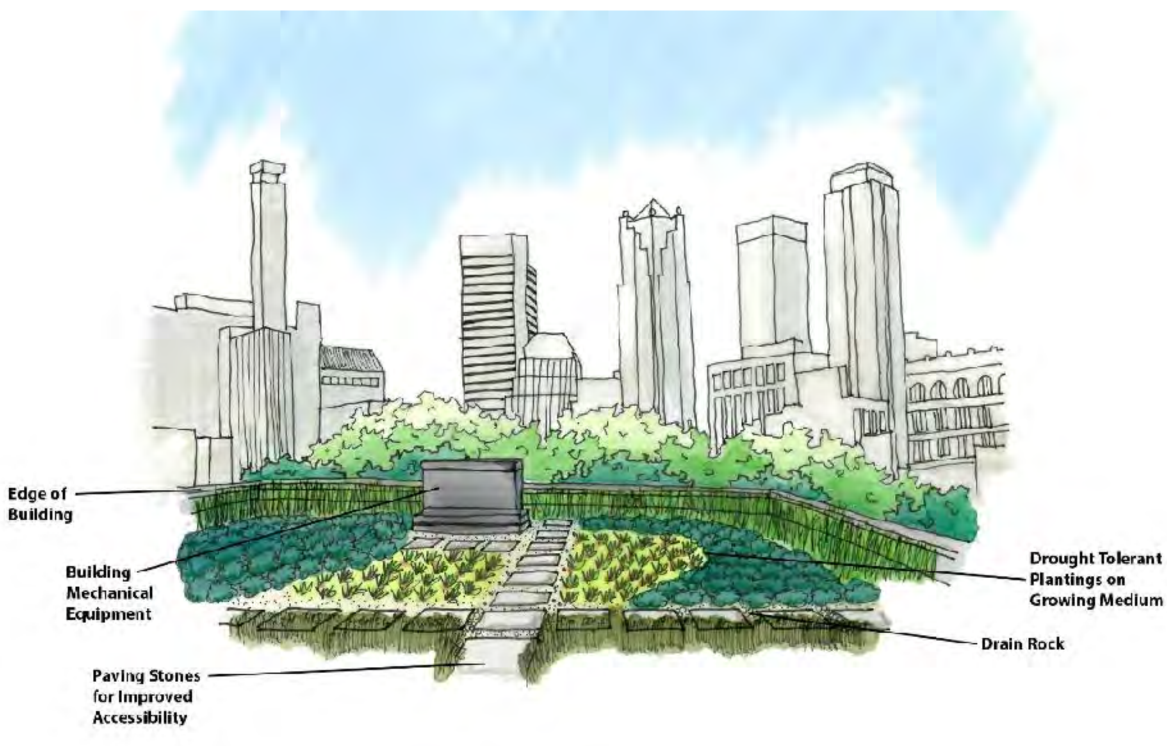
Vegetated roofs (also known as green roofs, living roofs, or ecoroofs) are alternative roof surfaces that typically consist of waterproofing and drainage materials and an engineered growing media that is designed to support plant growth. Vegetated roofs capture and temporarily store storm water runoff in the growing media before it is conveyed into the storm drain system. A portion of the captured storm water evaporates or is taken up by plants, which helps reduce runoff volumes, peak runoff rates, and pollutant loads on development sites.

There are two different types of vegetated roof systems: *intensive* vegetated roofs and *extensive* vegetated roofs. Intensive systems have a deeper growing media layer that ranges from 6 inches to 4 feet thick, which is planted with a wider variety of plants, including trees. By contrast, extensive systems typically have much shallower growing media (under 6 inches), which is planted with carefully selected drought tolerant vegetation. Extensive vegetated roofs are much lighter and less expensive than intensive vegetated roofs and are recommended for use on most development and redevelopment sites.

NOTE: This manual is intended for situations where the primary design objective of the vegetated roof is storm water management and, unless specified otherwise, addresses extensive roof systems.

Designers may wish to pursue other design objectives for vegetated roofs, such as energy efficiency, green building or LEED points, architectural considerations, visual amenities, and landscaping features, which are often maximized with intensive vegetated roof systems. However, these design objectives are beyond the scope of this manual.

Vegetated roofs typically contain a layered system of roofing, which is designed to support plant growth and retain water for plant uptake while preventing ponding on the roof surface. The roofs are designed so that water drains vertically through the media and then horizontally along a waterproofing layer towards the outlet. Extensive vegetated roofs are designed to have minimal maintenance requirements. Plant species are selected so that the roof does not need supplemental irrigation or fertilization after vegetation is initially established. Tray systems are also available with removable dividers allowing the media to meld together creating a seamless appearance, but with less difficulty in construction.



6.10.2 Planning and Physical Feasibility

Vegetated roofs are ideal for use on commercial, institutional, municipal, and multi-family residential buildings. They are particularly well suited for use on ultra-urban development and redevelopment sites. Vegetated roofs can be used on a variety of rooftops, including the following:

- Non-residential buildings (e.g., commercial, industrial, institutional, and transportation uses)
- Multi-family residential buildings (e.g., condominiums or apartments)
- Mixed-use buildings

The following criteria provided it **Table 6.10.1** shall be considered when evaluating the suitability of a green roof for a development site.

Table 6.10.1. Green Roof Constraints

Building Codes	Construction Cost	Structural Capacity of Roof	Retrofitting	Risk of Roof Leaks
Roof drains/emergency overflow requirements shall be met. If it is designed to be accessible, the access must adhere to City access and safety requirements.	Can cost between \$12 and \$25 per square foot, but cost savings exist due to increased energy efficiency, real estate desirability, and increased roof longevity.	A structural engineer, architect, or other qualified professional shall account for additional weight of potential water in design.	Area, age, accessibility, maintenance effort, and structural capacity shall be evaluated.	Well designed and installed green roofs have less problems with leaks than traditional roofs (see Chapter 9 in Weiler and Scholz-Barth (2009)).
Roof Access	**Roof Pitch**	**Roof Type**	**Non-Vegetated Areas**	
Opening 16 sq. ft. in area with a min. dimension of 24 in. required. Material delivery/stockpiling shall also be considered.	1 to 2% pitch maximizes treatment volume (T_v). Steeper pitch allowed (up to 8%) but reduces T_v and requires baffles/ grids/strips to prevent media slippage.	Concrete roof decks are preferred. Exposed treated wood and uncoated galvanized metal, may not be appropriate.	A maximum of 20% of the non-vegetated areas (access paths/ mechanical equipment/ photovoltaic panels/skylights) counts as part of the green roof for calculation purposes.	

The data listed below is necessary for the design of a green roof and shall be included with the development plan. See Appendix B for more information on required elements for the storm water management plan (SWMP).

- Architectural roof plan with rooftop pitches and downspout locations
- The proposed site design, including, buildings, parking lots, sidewalks, stairs and handicapped ramps, and landscaped areas for downspout discharge locations and bypass outfalls
- Information about downstream GIPs and receiving waters
- A planting plan prepared by a landscape architect, botanist, or other qualified professional

6.10.3 Design Requirements

The major design goal for vegetated roofs is to maximize runoff volume reduction. The rooftops have little TSS loading or loading removal. Designers may choose the baseline design (Level 1 (**RR 77**)) or choose an enhanced

(Level 2 (**RR 88**)) design that maximizes nutrient and runoff reduction. In general, most intensive vegetated roof designs will automatically qualify as being Level 2. **Table 6.10.2** lists the design criteria for Level 1 and 2 designs.

Table 6.10.2. Green Roof Design Guidance

Level 1 Design (RR:77)	Level 2 Design (RR: 88)
Tv = 1.0 (Rv)[1] (A)/12	Tv = 1.1 (Rv)[1] (A)/12
Depth of media up to 6 inches	Media depth > 6 inches
No more than 15% organic matter in media	
All Designs: Shall be in conformance to ASTM (2005) International Green (Vegetated) Roof Standards.	

1 Rv represents the runoff coefficient for a conventional roof, which will usually be 0.95. The runoff reduction rate applied to the vegetated roof is for "capturing" the Treatment Volume (Tv) compared to what a conventional roof would produce as runoff.

Figure 6.10.2. Vegetated Roof Cross-Sections *(Source: B. Hunt, NCSU)*

Sizing of Green Roof

Storm Water Quality

Vegetated roof areas shall be sized to capture a portion of the Treatment Volume (T_v). The required size of a vegetated roof will depend on several factors, including the porosity and hydraulic conductivity of the growing media and the underlying drainage materials. Site designers and planners shall consult with vegetated roof manufacturers and material suppliers for specific sizing guidelines. As a general sizing rule, the following equation can be used to determine the water quality treatment storage volume retained by a vegetated roof:

Equation 1. Treatment Volume for Green Roof

$$T_v = (RA * D * P)/12$$

Where,

T_v = storage volume (cu. ft.)
RA = vegetated roof area (sq. ft.)
D = media depth (in.)
P = media porosity (usually 0.3, but consult manufacturer specifications)

The resulting T_v can then be compared to the required T_v for the entire rooftop area (including all non-vegetated areas) to determine if it meets or exceeds the required T_v for Level 1 or Level 2 design, as shown in Table 6.10.2.

Structural Capacity of the Roof

Vegetated roofs can be limited by the additional weight of the fully saturated growing medium and plants in terms of the physical capacity of the roof to bear structural loads. The designer shall consult with a licensed structural engineer or architect to ensure that the building will be able to support the additional live and dead structural load and determine the maximum depth of the vegetated roof system and any needed structural reinforcement.

In most cases, fully-saturated extensive vegetated roofs have a maximum load of about 30 lbs./sq. ft., which is fairly similar to traditional new rooftops (12 to 15 lbs./sq. ft.) that have a waterproofing layer anchored with stone ballast. For an excellent discussion of vegetated roof structural design issues, consult Chapter 9 in Weiler and Scholz-Barth (2009) and ASTM E2397, *Standard Practice for Determination of Dead Loads and Live Loads Associated with Green (Vegetated) Roof Systems*.

Functional Elements of a Vegetated Roof System

A vegetated roof is composed of up to eight different systems or layers, from bottom to top, that are combined together to protect the roof and maintain a vigorous cover. Designers can employ a wide range of materials for each layer, which can differ in cost, performance, and structural load. The entire system as a whole shall be assessed to meet design requirements.

Some manufacturers offer proprietary vegetated roofing systems, whereas in other cases, the designer or architect shall assemble their own system, in which case they are advised to consult Weiler and Scholz-Barth (2009), Snodgrass and Snodgrass (2006), and Dunnett and Kingsbury (2004).

- **Deck Layer.** The roof deck layer is the foundation of a vegetated roof. It and may be composed of concrete, wood, metal, plastic, gypsum, or a composite material. The type of deck material determines the strength, load bearing capacity, longevity, and potential need for insulation in the vegetated roof system. In general, concrete decks are preferred for vegetated roofs, although other materials can be used as long as the appropriate system components are matched to them.

- **Waterproofing Layer.** All vegetated roof systems shall include an effective and reliable waterproofing layer to prevent water damage through the deck layer. A wide range of waterproofing materials can be used, including built up roofs, modified bitumen, single-ply, and liquid-applied methods (see Weiler and Scholz-Barth, 2009 and Snodgrass and Snodgrass, 2006). The waterproofing layer shall be 100% waterproof and have an expected life span as long as any other element of the vegetated roof system.

- **Insulation Layer.** Many vegetated rooftops contain an insulation layer, usually located above, but sometimes below, the waterproofing layer. The insulation increases the energy efficiency of the building and/or protects the roof deck (particularly for metal roofs). According to Snodgrass and Snodgrass (2006), the trend is to install insulation on the outside of the building, in part to avoid mildew problems.

- **Root Barrier (Optional).** The next layer of a vegetated roof system is an optional root barrier that protects the waterproofing membrane from root penetration. A wide range of root barrier options are described in Weiler and Scholz-Barth (2009). Chemical root barriers or physical root barriers that have been impregnated with pesticides, metals, or other chemicals that could leach into storm water runoff shall be avoided.

Figure 6.10.3. Flood Testing the Waterproofing Layer

Figure 6.10.4. Drainage Layer Installation

Figure 6.10.5. Delivery of Growing Media

Figure 6.10.6. Trays of Sedums

- **Drainage Layer and Drainage System.** A drainage layer is then placed between the optional root barrier and the growing media to quickly remove excess water from the vegetation root zone. The drainage layer shall consist of synthetic or inorganic materials (e.g., gravel, recycled polyethylene, etc.) that are capable of retaining water and providing efficient drainage. A wide range of prefabricated water cups or plastic modules can be used, as well as a traditional system of protected roof drains, conductors, and roof leader. The required depth of the drainage layer is governed by both the required storm water storage capacity and the structural capacity of the rooftop. ASTM E2396 and E2398 can be used to evaluate alternative material specifications.

- **Root-Permeable Filter Fabric**. A semi-permeable polypropylene filter fabric is normally placed between the drainage layer and the growing media to prevent the media from migrating into the drainage layer and clogging it.

- **Growing Media**. The next layer in an extensive vegetated roof is the growing media, which is typically 4 to 6 inches deep for extensive roofs and 6 inches or more for intensive roofs. The depth and composition of the media is described below.

- **Plant Cover.** The top layer of a vegetated roof typically consists of slow-growing, shallow-rooted, perennial, succulent plants that can withstand harsh conditions at the roof surface. An experienced design professional shall be consulted to select the plant species best suited to a given installation. Guidance on selecting the appropriate vegetated roof plants for hardiness zones in Nashville can be found in Snodgrass and Snodgrass (2006). A mix of base ground covers (usually Sedum species) and accent plants can be used to enhance the visual amenity value of a green roof.

Pre-Treatment

Pre-treatment is not needed for green roofs.

Filter Media Composition

The recommended growing media for extensive vegetated roofs is composed of approximately 80% to 90% lightweight inorganic materials, such as expanded slates, shales or clays, pumice, scoria, or other similar materials. The remaining media shall contain no more than 15% organic matter, normally well-aged compost. The percentage of organic matter shall be limited, since it can leach nutrients into the runoff from the roof and clog the permeable filter fabric. The growing media shall have a maximum water retention capacity of around 30%. It is advisable to mix the media in a batch facility prior to delivery to the roof. More information on growing media can be found in Weiler and Scholz-Barth (2009) and Snodgrass and Snodgrass (2006).

The composition of growing media for intensive vegetated roofs may be different, and it is often much greater in depth (e.g., 6 inches to 4 feet). If trees are included in the vegetated roof planting plan, the growing media shall provide enough volume for the root structure of mature trees.

Conveyance and Overflow

The drainage layer below the growth media shall be designed to convey the 10-year storm without backing water up to into the growing media. The drainage layer shall convey flow to an outlet or overflow system such as a traditional rooftop drainage system with inlets set slightly above the elevation of the vegetated roof surface. Roof drains immediately adjacent to the growing media shall be boxed and protected by flashing that extends at least 3 inches above the growing media to prevent clogging.

Vegetation and Surface Cover

A planting plan shall be prepared for a vegetated roof by a landscape architect, botanist, or other professional experienced with vegetated roofs, and it shall be reviewed and approved.

Plant selection for vegetated rooftops is an integral design consideration, which is governed by local climate and design objectives. The primary ground cover for most vegetated roof installations is a hardy, low-growing succulent, such as *Sedum, Delosperma, Talinum, Semperivum,* or *Hieracium* that is matched to the local climate conditions and can tolerate the difficult growing conditions found on building rooftops (Snodgrass and Snodgrass, 2006). Birmingham lies in the transition zone between USDA Plant Hardiness Zones 7b and 8a (AHS, 2003).

Other vegetation considerations:

- Plant choices can be much more diverse for deeper intensive vegetated roof systems. Herbs, forbs, grasses, shrubs, and even trees can be used, but designers should understand they have higher watering, weeding, and landscape maintenance requirements.
- The species and layout of the planting plan shall reflect the location of building, in terms of its height, exposure to wind, snow loading, heat stress, orientation to the sun, and shading by surrounding buildings. In addition, plants shall be selected that are fire resistant and able to withstand heat, cold, and high winds.
- Designers shall also match species to the expected rooting depth of the growing media, which can also provide enough lateral growth to stabilize the growing media surface. The planting plan should usually include several accent plants to provide diversity and seasonal color. For a comprehensive resource on vegetated roof plant selection, consult Snodgrass and Snodgrass (2006).
- It is also important to note that most vegetated roof plant species will not be native to the Southeast (which is in contrast to native plant recommendations for other storm water practices, such as bioretention and constructed wetlands).

- Given the limited number of vegetated roof plant nurseries in the region, designers should order plants 6 to 12 months prior to the expected planting date. It is also advisable to have plant materials contract-grown.
- When appropriate species are selected, most vegetated roofs will not require supplemental irrigation, except during the first year that the vegetated roof is being established or during periods of drought. Irrigation shall thus be provided as needed for full establishment and during drought periods. The planting window extends from the spring to early fall, although it is important to allow plants to root thoroughly before the first killing frost.
- Plants can be established using cuttings, plugs, mats, and, more rarely, seeding or containers. Several vendors also sell mats, rolls, or proprietary vegetated roof planting modules. For the pros and cons of each method, see Snodgrass and Snodgrass (2006).
- The goal for vegetated roof systems designed for storm water management is to establish a full and vigorous cover of low-maintenance vegetation that is self-sustaining and requires minimal mowing, trimming or weeding.
- The vegetated roof design shall include non-vegetated walkways (e.g., permeable paver blocks) to allow for easy access to the roof for weeding and making spot repairs.

Bioretention Material Specifications

Standards specifications for North American vegetated roofs continue to evolve, and no universal material specifications exist that cover the wide range of roof types and system components currently available. The American Society for Testing and Materials (ASTM) has recently issued several overarching vegetated roof standards, which are described and referenced in **Table 6.10.3.** Designers and reviewers shall also fully understand manufacturer specifications for each system component, particularly if they choose to install proprietary "complete" vegetated roof systems or modules.

Table 6.10.3 Extensive Vegetated Roof Material Specifications

Material	Specification
Roof	Structural Capacity shall conform to ASTM E2397-05, Practice for Determination of Live Loads and Dead Loads Associated with Green (Vegetated) Roof Systems. In addition, use standard test methods ASTM E2398-05 for Water Capture and Media Retention of Geocomposite Drain Layers for Green (Vegetated) Roof Systems, and ASTM E2399-05 for Maximum Media Density for Dead Load Analysis.
Waterproof Membrane	See Chapter 6 of Weiler and Scholz-Barth (2009) for waterproofing options that are designed to convey water horizontally across the roof surface to drains or gutter. This layer may sometimes act as a root barrier.
Root Barrier (Optional)	Impermeable liner that impedes root penetration of the membrane.
Drainage Layer	1 to 2-inch layer of clean, washed granular material, such as ASTM D 448 size No. 8 stone. Roof drains and emergency overflow shall be designed in accordance with Metro Codes.
Filter Fabric	Needled, non-woven, polypropylene geotextile. Density (ASTM D3776) > 16 oz./sq. yd., or approved equivalent. Puncture resistance (ASTM D4833) > 220 lbs., or approved equivalent.
Growth Media	85% lightweight inorganic materials and 15% organic matter (e.g. well-aged compost). Media shall have a maximum water retention capacity of around 30%. Media shall provide sufficient nutrients and water holding capacity to support the proposed plant materials. Determine acceptable saturated water permeability using ASTM E2396-05.
Plant Materials	Low plants such as sedum, herbaceous plants, and perennial grasses that are shallow-rooted, self-sustaining, and tolerant of direct sunlight, drought, wind, and frost. See ASTM E2400-06, Guide for Selection, Installation and Maintenance of Plants for Green (Vegetated) Roof Systems.

6.10.4 Construction, Protection, and Maintenance Requirements

All GIPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all GIPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For City policies, additional guidance, and forms pertaining to GIP protection, inspection, and maintenance requirements, see Appendix B of this manual.

Requirements During Construction

- Care shall be given to avoid damage to the waterproofing membrane during installation of the green roof. If the integrity of the membrane is compromised in a manner that may cause leaks or roof damage, the area shall be identified and repaired. Visually inspect for damage and test the membrane for water tightness prior to installation of the engineered growing media.
- If the roof is sloped, stabilization measures may be required before installing the green roof to prevent soil from sliding down the roof. Some situations may allow the stabilization measures to be incorporated into the roof structure.
- Install the green roof according to the manufacturer's instructions. Usually the root barrier layer, walkway, and irrigation system are installed first.
- To help prevent compaction of the engineered growing media, heavy foot traffic shall be kept off green roof surfaces during and after construction.
- Construction contracts shall contain a replacement warranty that covers at least three growing seasons to help ensure adequate growth and survival of the vegetation planted on a green roof.

Protection Requirements

- Consider signage and appropriate receptacles for litter and pet waste if the green roof is accessible.
- Provide signage for the GIP.
  - Allows for easy identification and location of the GIP.
  - Serves as a general education tool, making those responsible for property, landscape or GIP maintenance, and the general public aware of the water quality features of the GIP and to avoid encroachment.

Inspection Requirements

- Access to the site is adequate for inspection and maintenance.
- Area is clean (trash, debris, grass clippings, weeds etc. removed).
- Inspect green roof for dead or dying vegetation.
- Inlet and outlet pipes are free of trash, debris, etc. Inspect for ponding that may signify clogging at inflow points.
- Inspect waterproof membrane.
- No signs of structural deficiency or settling.

Maintenance Requirements

- Dead vegetation shall be removed along with any woody vegetation.
- Plant replacement vegetation as needed.
- Remove trash, debris, and other pollutants from the rooftop.
- Remove any accumulated sediment or debris.

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6.11 Permeable Pavement

Figure 6.11.1. Permeable Pavement in Railroad Park in Birmingham, AL

DEVELOPMENT ATTRIBUTES

Construction Cost — HIGH

Operation and Maintenance Cost — HIGH

Ground-Level Encroachment — HIGH

Building Footprint Enhancement — MODERATE

Triple Bottom-Line Benefits — MODERATE

Description:

Permeable pavements allow storm water runoff to filter through voids in the pavement surface into an underlying stone reservoir, where it is temporarily stored and/or infiltrated. Porous paving systems have several design variants. The four major categories are: 1) pervious concrete; 2) modular block systems; 3) grass pavers; and 4) gravel pavers. All have a similar structure, consisting of a surface pavement layer, an underlying stone aggregate reservoir layer, and a filter layer or fabric installed on the bottom.

Variations:

Variations include permeable interlocking pavers, concrete grid pavers, and plastic reinforced grid pavers.

Key Advantages:

- Runoff volume reduction
- Can increase aesthetic value
- Provide water quality treatment

Key Limitations:

- High cost and maintenance requirements
- Limited to low traffic areas with limited structural loading
- Potential issues with handicap access
- Infiltration can be limited by underlying soil properties
- Not effective on steep slopes

PERFORMANCE STANDARD COMPLIANCE					
Water Quality			Stream Channel Protection	Overbank Flood Protection	Extreme Flood Protection
Treatment Volume		80% TSS Removal			
Level 1	Level 2				
38 RR Credit	72 RR Credit	✓	▶	▶	▶

✓ Suitable for this practice

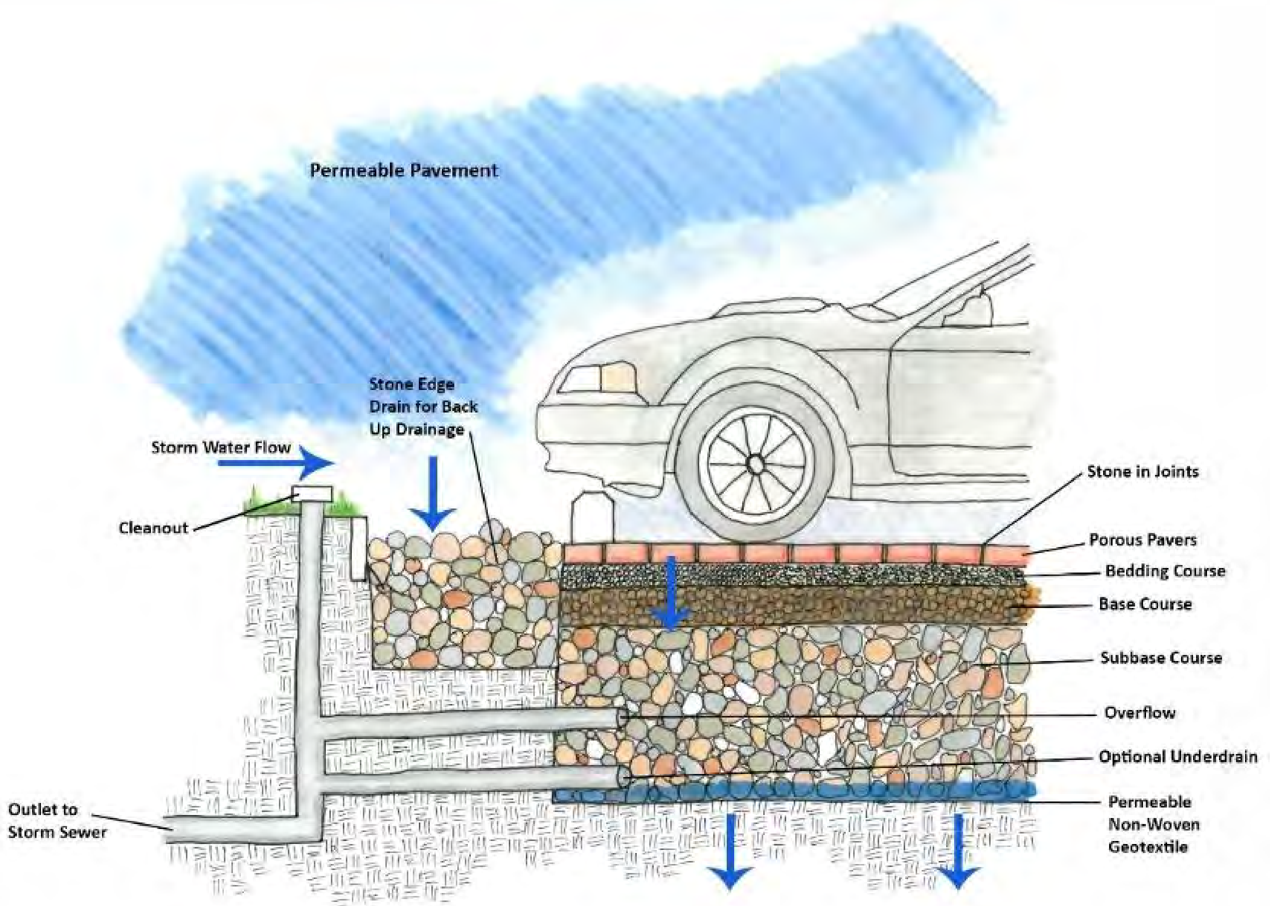
▶ Provides partial benefits

6.11.1 General Application

Permeable pavements are alternative paving surfaces that allow storm water runoff to filter through voids in the pavement surface into an underlying stone reservoir, where it is temporarily stored and/or infiltrated. Permeable pavements consist of a surface pavement layer, an underlying stone aggregate reservoir layer and a filter layer or fabric installed on the bottom.

The thickness of the reservoir layer is determined by both a structural and hydrologic design analysis. The reservoir layer serves to retain storm water and also supports the design traffic loads for the pavement. In low-infiltration soils, some or all of the filtered runoff is collected in an underdrain and returned to the storm drain system. If infiltration rates in the native soils permit, permeable pavement can be designed without an underdrain to enable full infiltration of runoff. A combination of these methods can be used to infiltrate a portion of the filtered runoff.

Permeable pavement is typically designed to treat storm water that falls on the actual pavement surface area, but it may also be used to accept run-on from small adjacent impervious areas, such as impermeable driving lanes or rooftops. However, careful sediment control is needed for any run-on areas to avoid clogging of the down-gradient permeable pavement. Permeable pavement has been used at commercial, institutional, and residential sites in spaces that are traditionally impervious. Permeable pavement promotes a high degree of runoff volume reduction and nutrient removal, and it can also reduce the effective impervious cover of a development site.



6.11.2 Planning and Physical Feasibility

Since permeable pavement has a very high runoff reduction capacity, it should always be considered as an alternative to conventional pavement. Permeable pavement is subject to the same feasibility constraints as most infiltration practices. The following criteria provided in **Table 6.11.1** shall be considered when evaluating the suitability of permeable pavement for a development site.

Table 6.11.1. Permeable Pavement Constraints

Available Space	**Contributing Drainage Area**	**High Loading Situations**	**Hotspot Land Uses**	**Hydraulic Head needed**	**Irrigation or Baseflow**	**Pavement Slope**
Additional space not required	Runoff to permeable pavement shall not exceed twice the surface area of the permeable pavement (for Level 1 design), and it shall be as close to 100% impervious as possible.	Not intended to treat sites with high sediment or trash/debris loads.	Generally, not allowed, refer to Appendix D.	2-4 feet if underdrain is used. Otherwise, minimal head required.	Avoid access non-storm water run-on.	Steep slopes can reduce the storm water storage capability of and cause shifting of surface and base materials. A terraced design can be used in sloped areas, especially when the local slope is several percent or greater.
Setbacks	**Shallow Bedrock**	**Site Topography Needed**	**Soils Requirement**	**Underdrain**	**Utility Requirement**	**Water Table Requirement**
Water supply wells require 100'. Septic systems require 50'. For structures and roads, refer to Table 6.11.2. Not allowed in right of way.	Underdrain required when bedrock is less than 2' beneath the invert.	Slope greater than 1% and less than 5%.	HSG C or D need an underdrain.	Min. 0.5% slope	Consider clearance for all utilities. Min. 5' from down-gradient wet utility lines.	2' of separation

The data listed below is necessary for the design of permeable pavement areas and shall be included with the development plan. See Appendix B for more information on required elements for the storm water management plan (SWMP).

- Existing and proposed site, topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Water surface elevation of nearby water systems as well as the depth to seasonally high groundwater.
- If no underdrain is proposed for the permeable pavement area, then infiltration testing of native soils at proposed elevation of bottom of permeable pavement area is required. See Appendix E for more information.
- If no underdrain is proposed, then the Infiltration Feasibility form provided in Appendix B shall be submitted with the SWMP.

6.11.3 Design Requirements

The major design goal of permeable pavement is to maximize runoff reduction. To this end, designers may choose to use a baseline permeable pavement design (Level 1 (**RR 38**) or an enhanced design (Level 2 (**RR 72**)) that maximizes runoff reduction. To qualify for Level 2, the design shall meet all design criteria shown in the right hand column of **Table 6.11.2**. Typical details are located in Appendix F.

Table 6.11.2. Permeable Pavement Design Criteria

Level 1 Design	Level 2 Design
Tv [1]= (1)(Rv)(A) 3630	Tv[1] = (1.1)(Rv)(A) 3630
Soil infiltration ≤ 0.5 in./hr.	Soil infiltration rate > 0.5 in./hr.
Maximum contributing drainage area is twice the permeable surface area.	The permeable material handles only rainfall on its surface.
Underdrain required	Underdrain not required; OR If an underdrain is used, a 12-inch stone sump shall be provided below the underdrain invert

1 A = Area in acres

Permeable pavement can be installed at the following three scales:

- The smallest scale is termed Micro-Scale Pavements, which applies to converting impervious surfaces to permeable ones on small lots and redevelopment projects, where the installations may range from 250 to 1000 square feet in total area. Where redevelopment or retrofitting of existing impervious areas results in a larger foot-print of permeable pavers (small-scale or large-scale, as described below), the designer shall implement the Load Bearing, Observation Well, Underdrain, Soil Test, and Building Setback criteria associated with the applicable scale.
- Small-scale pavement applications treat portions of a site between 1,000 and 10,000 square feet in area and include areas that only occasionally receive heavy vehicular traffic.
- Large scale pavement applications exceed 10,000 square feet in area and typically are installed within portions of a parking lot.

Table 6.11.3 outlines the different design requirements for each of the three scales of permeable pavement installation.

Table 6.11.3. The Three Design Scales for Permeable Pavement

Design Factor	Micro-Scale Pavement	Small-Scale Pavement	Large-Scale Pavement
Impervious Area Treated	250 to 1,000 sq. ft.	1,000 to 10,000 sq. ft.	More than 10,000 sq. ft.
Typical Applications	Driveways, Walkways, Courtyards, Plazas, Individual Sidewalks	Sidewalk Network, Fire Lanes, Road, Shoulders (private), Spill-Over Parking, Plazas	Parking Lots with more than 40 spaces
Load Bearing Capacity	Foot traffic, Light vehicles	Light vehicles	Heavy vehicles (moving & parked)
Reservoir Size	Infiltrate or detain some or all of the T_v	Infiltrate or detain the full T_v	
External Drainage Area?	No	Can drain twice the area of impervious cover onto external drainage area with Level 1 design.	
Observation Well	No	No	Yes
Underdrain?	Rare	Depends on the soils	Back-up underdrain
Required Soil Tests	Two per practice	Four per practice	Four + one per every additional 5,000 ft^2
Suggested Building Setbacks	5 feet down-gradient, 25 feet up-gradient	10 feet down-gradient, 50 feet up-gradient	25 feet down-gradient, 100 feet up-gradient

Regardless of the design scale of the permeable pavement installation, the designer shall carefully consider the expected traffic load at the proposed site and the consequent structural requirements of the pavement system. Sites with heavy traffic loads will require a thick aggregate base. In contrast, most micro-scale applications should have little or no traffic flow to contend with.

Structural Design. If permeable pavement will be used in a parking lot or other setting that involves vehicles, the pavement surface shall be able to support the maximum anticipated traffic load. The structural design process will vary according to the type of pavement selected, and the manufacturer's specific recommendations shall be consulted. The thickness of the permeable pavement and reservoir layer shall be sized to support structural loads and to temporarily store the design storm volume (e.g., the water quality, channel protection, and/or flood control volumes). On most new development and redevelopment sites, the structural support requirements will dictate the depth of the underlying stone reservoir. The structural design of permeable pavements involves consideration of four main site elements:

- Total traffic;
- In-situ soil strength;
- Environmental elements; and
- Bedding and Reservoir layer design.

The resulting structural requirements may include, but are not limited to, the thickness of the pavement, filter, and reservoir layer. Designers shall note that if the underlying soils have a low California Bearing Ratio (CBR) (less than 4%), they may need to be compacted to at least 95% of the Standard Proctor Density, which generally rules out their use for infiltration. Designers shall determine structural design requirements by consulting transportation design guidance sources, such as the following:

- ALDOT Standards (2017; or latest edition);
- AASHTO Guide for Design of Pavement Structures (1993); and
- AASHTO Supplement to the Guide for Design of Pavement Structures (1998).

Sizing of Permeable Pavement

Storm Water Quality

Permeable pavement is typically sized to store the complete water quality Treatment Volume (T_v) or another design storm volume in the reservoir layer. Modeling has shown that this simplified sizing rule approximates an 80% average annual rainfall volume removal for subsurface soil infiltration rates up to one inch per hour. More conservative values are given because both local and national experience has shown that clogging of the permeable material can be an issue, especially with larger contributing areas carrying significant soil materials onto the permeable surface. The infiltration rate typically will be less than the flow rate through the pavement so that some underground reservoir storage will usually be required.

Designers shall initially assume that there is no outflow through underdrains, using Equation 1 to determine the depth of the reservoir layer, assuming runoff fully infiltrates into the underlying soil:

Equation 1. Depth of Reservoir Layer with no Underdrain

$$d_p = \frac{\{(d_c \times R) + P - (i/_2 \times t_f)\}}{V_r}$$

Where:

d_p = The depth of the reservoir layer (ft.)

d_c = The depth of runoff from the contributing drainage area (not including the permeable paving surface) for the Treatment Volume (T_v/A_c), or other design storm (ft.)

R	=	A_c/A_p = The ratio of the contributing drainage area (A_c, not including the permeable paving surface) to the permeable pavement surface area (A_p) [NOTE: With reference to Table 6.11.3, the maximum value for the Level 1 design is R = 2, (the external drainage area A_c is twice that of the permeable pavement area Ap; and for Level 2 design R = 0 (the drainage area is made up solely of permeable pavement A_p].
P	=	The rainfall depth for the Treatment Volume (Level 1 = 1 inch; Level 2 = 1.1 inch), or other design storm (ft.)
i	=	The field-verified infiltration rate for native soils (ft./day)
t_f	=	The time to fill the reservoir layer (day) – typically 2 hours or 0.083 day
V_r	=	The void ratio for the reservoir layer (0.4)

The maximum allowable depth of the reservoir layer is constrained by the maximum allowable drain time, which is calculated using Equation 2.

Equation 2. Maximum Depth of Reservoir Layer

$$d_{p-m} = \frac{(i/2 \times t_d)}{V_r}$$

Where:

d_{p-max}	=	The maximum depth of the reservoir layer (ft.)
i	=	The field-verified infiltration rate for native soils (ft./day)
t_d	=	The maximum allowable time to drain the reservoir layer, typically 1 to 2 days
V_r	=	The void ratio for the reservoir layer (0.4)

The following design assumptions apply to Equations 1 and 2:

- The contributing drainage area (A_c) shall not contain pervious areas.
- For design purposes, the native soil infiltration rate (i) shall be the field-tested soil infiltration rate divided by a factor of safety of 2. The minimum acceptable native soil infiltration rate is 0.5 inches/hr.
- The void ratio (V_r) for No. 57 stone = 0.40
- Max. drain time for the reservoir layer shall be not less than 24 nor more than 48 hours.

If the depth of the reservoir layer is too great (i.e. d_p exceeds d_{p-max}), or the verified soil infiltration rate is less than 0.5 inches per hour, then the design method typically changes to account for underdrains. The storage volume in the pavements shall account for the underlying infiltration rate and outflow through the underdrain. In this case, the design storm shall be routed through the pavement to accurately determine the required reservoir depth. Alternatively, the designer may use Equations 3 through 5 to approximate the depth of the reservoir layer for designs using underdrains.

Equation 3 can be used to approximate the outflow rate from the underdrain. The hydraulic conductivity, *k*, of gravel media is very high (~17,000 ft./day). However, the permeable pavement reservoir layer will drain increasingly slower as the storage volume decreases (i.e. the hydraulic head decreases). To account for this change, a conservative permeability coefficient of 100 ft./day can be used to approximate the average underdrain outflow rate.

Equation 3. Outflow through Underdrain

$$q_u = k \times m$$

Where:

q_u	=	Outflow through the underdrain (per outlet pipe, assumed 6-inch diameter)(ft./day)
k	=	Hydraulic conductivity for the reservoir layer (ft./day – assume 100 ft./day)
m	=	Underdrain pipe slope (ft./ft.)

Once the outflow rate through the underdrain has been approximated, Equation 4 is used to determine the depth of the reservoir layer needed to store the design storm.

Equation 4. Depth of Reservoir Layer with Outflow through Underdrain

$$d_p = \frac{\{(d_c \times R) + P - (i/_2 \times t_f) - (q_u \times t_f)\}}{V_r}$$

Where:

d_p	=	Depth of the reservoir layer (ft.)
d_c	=	Depth of runoff from the contributing drainage area (not including the permeable pavement surface) for the Treatment Volume (Tv/A_c), or other design storm (ft.)
R	=	A_c/A_p = The ratio of the contributing drainage area, A_j (not including the permeable pavement surface) to the permeable pavement surface area (A_p)
P	=	The rainfall depth for the Treatment Volume (Level 1 = 1 inch; Level 2 = 1.1 inch), or other design storm (ft.)
i	=	The field-verified infiltration rate for the native soils (ft./day)
t_f	=	The time to fill the reservoir layer (day) – typically 2 hours or 0.083 day
V_r	=	Underdrain pipe slope (ft./ft.)
q_u	=	Outflow through Underdrain (ft/day)

The maximum allowable depth of the reservoir layer is constrained by the maximum allowable drain time, which is calculated using Equation 5.

Equation 5. Maximum Depth of Reservoir Layer with Outflow through Underdrain

$$d_{p-m} = \frac{\{(i/_2 \times t_d) - (q_u \times t_d)\}}{V_r}$$

Where:

d_{p-max}	=	The maximum depth of the reservoir layer (ft.)
i	=	The field-verified infiltration rate for the native soils (ft./day)
V_r	=	The void ratio for the reservoir layer (0.4)
t_d	=	The time to drain the reservoir layer (day – typically 1 to 2 days)
q_u	=	Outflow through Underdrain (ft/day)

If the depth of the reservoir layer is still too great (i.e. d_p exceeds $d_{p-max)}$, the number of underdrains can be increased, which will increase the underdrain outflow rate. Permeable pavement can also be designed to address, in whole or in part, the detention storage needed to comply with channel protection and/or flood control requirements. The designer can model various approaches by factoring in storage within the stone aggregate layer, expected infiltration, and any outlet structures used as part of the design. Routing calculations can also be used to provide a more accurate solution of the peak discharge and required storage volume. Once runoff passes through the surface of the permeable pavement system, designers shall calculate outflow pathways to handle subsurface flows. Subsurface flows can be regulated using underdrains, the volume of storage in the reservoir layer, and the bed slope of the reservoir layer.

Soil Infiltration Rate Testing

In order to determine if an underdrain will be needed, one shall measure the infiltration rate of subsoils at the invert elevation of the permeable pavement area. The infiltration rate of subsoils shall exceed 0.5 inch per hour for permeable pavement areas. On-site soil infiltration rate testing procedures are outlined in Appendix E. The number of soil tests varies base on the size of the permeable pavement area:

- < 1,000 ft^2 = 2 tests
- 1,000 – 10,000 ft^2 = 4 tests
- >10,000 ft^2 = 4 tests + 1 test for every additional 5,000 ft^2

Soil testing is not needed for Level 1 permeable pavement areas where an underdrain is used. If an underdrain with a gravel sump is used for Level 2, the bottom of the sump shall be at least two feet above bedrock and the seasonally high groundwater table.

Geometry and Drawdowns

Elevated Underdrain. To promote greater runoff reduction for permeable pavement located on marginal soils, an elevated underdrain shall be installed with a stone jacket that creates a 12 to 18 inch deep storage layer below the underdrain invert. The void storage in this layer can help qualify a site to achieve Level 2 design.

Rapid Drawdown. When possible, permeable pavement shall be designed so that the target runoff reduction volume stays in the reservoir layer for at least 36 hours before being discharged through an underdrain.

Conservative Infiltration Rates. Designers shall always decrease the measured infiltration rate by a factor of 2 during design to approximate long term infiltration rates.

Pre-Treatment

Careful sediment control is needed for any run-on areas to avoid clogging of the down-gradient permeable pavement. Pre-treatment for most permeable pavement applications is not necessary, since the surface acts as pre-treatment to the reservoir layer below.

Conveyance and Overflow

Permeable pavement designs shall include methods to convey larger storms (e.g., 2-yr, 10-yr) to the storm drain system. The following is a list of methods that can be used to accomplish this:

- Place a perforated pipe horizontally near the top of the reservoir layer to pass excess flows after water has filled the base. The placement and/or design shall be such that the incoming runoff is not captured (e.g., placing the perforations on the underside only).
- Increase the thickness of the top of the reservoir layer by as much as 6 inches (i.e., create freeboard). The design computations used to size the reservoir layer often assume that no freeboard is present.
- Create underground detention within the reservoir layer of the permeable pavement system. Reservoir storage may be augmented by corrugated metal pipes, plastic or concrete arch structures, etc.
- Route excess flows to another detention or conveyance system that is designed for the management of extreme event flows.
- Set the storm drain inlets flush with the elevation of the permeable pavement surface to effectively convey excess storm water runoff past the system (typically in remote areas). The design shall also make allowances for relief of unacceptable ponding depths during larger rainfall events.

Reservoir Layer

The thickness of the reservoir layer is determined by runoff storage needs, the infiltration rate of in situ soils, structural requirements of the pavement sub-base, depth to water table and bedrock, and frost depth conditions. A professional shall be consulted regarding the suitability of the soil subgrade.

- The reservoir below the permeable pavement surface shall be composed of clean, washed stone aggregate and sized for both the storm event to be treated and the structural requirements of the expected traffic loading.
- The storage layer may consist of clean washed No. 57 stone, although No. 2 stone is preferred because it provides additional storage and structural stability.
- The bottom of the reservoir layer shall be completely flat so that runoff will be able to infiltrate evenly through the entire surface.

Maintenance Reduction Features

Maintenance is a crucial element to ensure the long-term performance of permeable pavement. The most frequently cited maintenance problem is surface clogging caused by organic matter and sediment which can be reduced by the following measures:

- **Periodic Vacuum Sweeping.** The pavement surface is the first line of defense in trapping and eliminating sediment that may otherwise enter the stone base and soil subgrade. The rate of sediment deposition shall be monitored and vacuum sweeping done once or twice a year. This frequency shall be adjusted according to the intensity of use and deposition rate on the permeable pavement surface. At least one sweeping pass shall occur at the end of winter.
- **Protecting the Bottom of the Reservoir Layer.** One of two methods is required to protect the bottom of the reservoir layer from intrusion by underlying soils. The first method involves covering the bottom with nonwoven, polypropylene geotextile that is permeable, although some practitioners recommend avoiding the use of filter fabric since it may become a future plane of clogging within the system. Permeable filter fabric is still recommended to protect the excavated sides of the reservoir layer in order to prevent soil piping. The second method is to form a barrier of choker stone and sand. In this case, underlying native soils shall be separated from the reservoir base/subgrade layer by a thin 2 to 4-inch layer of clean, washed, choker stone (ASTM D 448 No. 8 stone) covered by a layer of 6 to 8 inches of course sand.
- **Observation Well.** An observation well, consisting of a well-anchored, perforated 4 to 6-inch (diameter) PVC pipe that extends vertically to the bottom of the reservoir layer, shall be installed at the downstream end of all large-scale permeable pavement systems. The observation well shall be fitted with a lockable cap installed flush with the ground surface (or under the pavers) to facilitate periodic inspection and maintenance. The observation well is used to observe the rate of drawdown within the reservoir layer following a storm event.
- **Overhead Landscaping.** Check the area of parking lots required to be in landscaping. Large-scale permeable pavement applications shall be carefully planned to integrate this landscaping in a manner that maximizes runoff treatment and minimizes the risk that sediment, mulch, grass clippings, leaves, nuts, and fruits will inadvertently clog the paving surface.

Underdrain and Underground Storage Layer

The use of underdrains is recommended when there is a reasonable potential for infiltration rates to decrease over time, when underlying soils have an infiltration rate of 0.5 inches per hour or less, when shallow bedrock is present, or when soils must be compacted to achieve a desired Proctor density. Underdrains can also be used to manage extreme storm events to keep detained storm water from backing up into the permeable pavement.

- The underdrain shall be surrounded by a minimum of 3 inches of washed #57 stone above and on each side of the pipe. Above the stone, two inches of choking stone is needed to protect the underdrain from blockage.
- The underdrain outlet can be fitted with a flow-reduction orifice as a means of regulating the storm water detention time. The minimum diameter of any orifice shall be 0.5 inch.
- An underdrain(s) can also be installed and capped at a downstream structure as an option for future use if maintenance observations indicate a reduction in the soil permeability.

Permeable Pavement Material Specifications

Permeable pavement material specifications vary according to the specific pavement product selected. **Table 6.11.4** describes general material specifications for the component structures installed beneath the permeable pavement. **Table 6.11.5** provides specifications for general categories of permeable pavements. Designers shall consult manufacturer's technical specifications for specific criteria and guidance.

Table 6.11.4. Material Specifications for Underneath the Pavement Surface

Material	Specification	Notes
Bedding Layer	Pervious Concrete: None Interlocking Pavers: 2 in. depth of No. 8 stone over 3 to 4 inches of No. 57	ASTM D448 size No. 8 stone (e.g. 3/8 to 3/16 inch in size). Shall be double-washed and clean and free of all fines.
Reservoir Layer	Pervious Concrete: No. 57 or No. 2 stone Interlocking Pavers: No. 57 or No. 2 stone	ASTM D448 size No. 57 stone (e.g. 1 1/2 to 1/2 inch in size); No. 2 Stone (e.g. 3 inch to 3/4 inch in size). Depth is based on the pavement structural and hydraulic requirements. Shall be double-washed and clean and free of all fines.
Underdrain	Use a minimum 4-inch diameter Schedule 40 or SDR 35 smooth wall PVC pipe, with 3/8-inch perforations at 6 inches on center; each underdrain installed at a minimum 0.5% slope located 20 feet or less from the next pipe (or equivalent corrugated HDPE may be used for smaller load-bearing applications). Perforated pipe installed for the full length of the permeable pavement cell, and non-perforated pipe, as needed, is used to connect with the storm drain system. T's and Y's installed as needed, depending on the underdrain configuration. Extend cleanout pipes to the surface with vented caps at the Ts and Ys.	
Either Filter Layer or (See Filter Fabric below below)	The underlying native soils shall be separated from the stone reservoir by a thin, 2- to 4-inch layer of choker stone (e.g. No. 8) covered by a 6- to 8-inch layer of coarse sand (e.g. ASTM C 33, 0.02-0.04 inch).	
Filter Fabric (optional)	The underlying native soils shall be separated from the stone reservoir by a thin, 2- to 4-inch layer of choker stone (e.g. No. 8) covered by a 6- to 8-inch layer of coarse sand (e.g. ASTM C 33, 0.02-0.04 inch).	The sand shall be placed between the stone reservoir and the choker stone, which shall be placed on top of the underlying native soils.
Impermeable Liner (if needed)	Use a thirty mil (minimum) PVC Geomembrane liner covered by 8 to 12 oz./sq. yd.[2] non-woven geotextile.	
Observation Well	Include at least 2 observation wells/cleanouts for each underdrain (at upstream and downstream ends). Use a non-perforated Schedule 40PVC pipe at least 4 inches in diameter and extend to surface with a watertight, removable cap.	

Table 6.11.5. Different Permeable Pavement Specifications

Material	Specification	Notes
Permeable Interlocking Concrete Pavers	Surface open area: 5% to 15%. Thickness: 3.125 inches for vehicles. Compressive strength: 55 Mpa (~8000 psi). Open void fill media: aggregate	Shall conform to ASTM C936 specifications. Reservoir layer required to support the structural load.
Concrete Grid Pavers	Open void content: 20% to 50%. Thickness: 3.5 inches. Compressive strength: 35 Mpa(~5000 psi). Open void fill media: aggregate, topsoil and grass, coarse sand.	Shall conform to ASTM C 1319 specifications. Reservoir layer required to support the structural load.
Plastic Reinforced Grid Pavers	Void content: depends on fill material. Compressive strength: varies, depending on fill material. Open void fill media: aggregate, topsoil and grass, coarse sand.	Reservoir layer required to support the structural load.

6.11.4 Construction, Protection, and Maintenance Requirements

All GIPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all GIPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For City policies, additional guidance, and forms pertaining to GIP protection, inspection, and maintenance requirements, see Appendix B of this manual.

Requirements During Construction

- Avoid undue compaction, which could affect the soils' infiltration capability.

Protection Requirements

- Provide signage for the GIP.
    - Allows for easy identification and location of the GIP.
    - Serves as a general education tool, making those responsible for property, landscape or GIP maintenance, and the general public aware of the water quality features of the GIP and to avoid encroachment.
- Design the layout of the permeable pavement such that maintenance equipment can easily achieve access.

Inspection Requirements

- Inspect the permeable pavement and underdrain for clogging or sediment buildup.
- Inspect the property that drains to the permeable pavement for erosion, exposed soil, or stockpiles of other potential pollutants.

Maintenance Requirements

- Conduct mowing, weeding, and trash removal as needed to prevent obstacles to the intended drainage and maintenance of the permeable paver system. Remove grass clipping and other landscaping debris.
- Keep outlets clear of debris to prevent clogging, clear if necessary.
- Keep inlets clear of debris to prevent clogging, clear if necessary.
- Prevent clogging of the aggregate through maintenance with vacuum trucks and street sweepers.
- Inspect underdrain cleanout to ensure storm water infiltrates properly. Clean-out underdrain if necessary.

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6.12 Infiltration Trench

Figure 6.12.1. Infiltration Area at Railroad Park, Birmingham, AL

DEVELOPMENT ATTRIBUTES

Construction Cost	MODERATE
Operation and Maintenance Cost	MODERATE
Ground-Level Encroachment	LOW
Building Footprint Enhancement	MODERATE
Triple Bottom-Line Benefits	MODERATE

Infiltration

80% TSS Removal

Description:

An infiltration trench is an excavated trench filled with stone aggregate used to capture and allow infiltration of storm water runoff into the surrounding soils from the bottom and sides of the trench. Runoff from each rain event is captured and treated primarily through settling and filtration.

Variations:

Constructed without underdrain in soils with measured infiltration rates greater than 0.5 inch per hour and with an underdrain in less permeable soils.

Key Advantages:

- Provides for groundwater recharge
- Good for small sites with porous soils
- Cost effective
- High community acceptance when integrated into a development

Key Limitations:

- Potential for groundwater contamination
- High clogging potential; shall not be used on sites with fine-particle soils (clays or silts) in drainage area
- Cannot be used in karst soils
- Geotechnical testing required
- Community perceived concerns with mosquitoes and safety

PERFORMANCE STANDARD COMPLIANCE					
Water Quality			Stream Channel Protection	Overbank Flood Protection	Extreme Flood Protection
Treatment Volume		80% TSS Removal			
Level 1	Level 2				
43 RR Credit	89 RR Credit	✓	▶	▶	▶

✓ Suitable for this practice

▶ Provides partial benefits

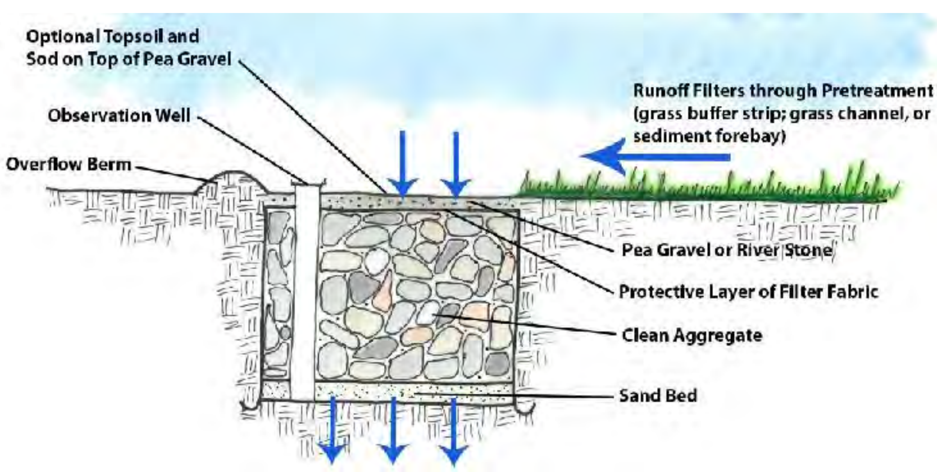
6.12.1 General Application

Infiltration trenches are excavations typically filled with stone to create an underground reservoir for storm water runoff. The runoff volume gradually exfiltrates through the bottom and sides of the trench into the subsoil over a 2-day period and eventually reaches the water table. By diverting runoff into the soil, an infiltration trench not only treats the water quality volume but also helps to preserve the natural water balance on a site and can recharge groundwater and preserve base flow. Due to this fact, infiltration systems are limited to areas with highly porous soils where the water table and/or bedrock are located well below the bottom of the trench.

Due to the relatively narrow shape, infiltration trenches can be adapted to many different types of sites and can be utilized in retrofit situations, but they shall be carefully sited to avoid the potential of groundwater contamination. They are generally suited for medium-to-high density residential, commercial, and institutional developments. To protect groundwater from potential contamination, runoff from designated hotspot land uses or activities shall not be infiltrated. Infiltration trenches shall not be used for manufacturing and industrial yards, where there is a potential for high concentrations of soluble pollutants and heavy metals, in areas with a high pesticide concentration or in areas with karst geology. Adequate geotechnical testing by qualified individuals and in accordance with Appendix D shall be conducted to check for potential contamination issues.

Figure 6.12.2. Infiltration Trench in Papermaker's Garden, Columbia College, Chicago, IL

Using the natural filtering properties of soil, infiltration trenches can remove a wide variety of pollutants from storm water through sorption, precipitation, filtering, and bacterial and chemical degradation. Due to their high potential for failure, infiltration trenches shall only be considered for sites where upstream sediment control can be ensured. Infiltration trenches are not intended to trap sediment and shall always be designed with a sediment forebay and grass channel or filter strip or other appropriate pretreatment measures to prevent clogging and failure. The subsoil shall be sufficiently permeable to provide a reasonable infiltration rate and the water table is low enough to prevent groundwater contamination. Infiltration trenches are applicable primarily for impervious areas where there are not high levels of fine particulates (clay/silt soils) in the runoff and shall only be considered for sites where the sediment load is relatively low. Infiltration trenches can either be used to capture sheet flow from a drainage area or function as an off-line device.



6.12.2 Planning and Physical Feasibility

Infiltration trenches can only be applied where there is adequate subsoil infiltration and where the risk of groundwater contamination is low. The following criteria provided in **Table 6.12.1** shall be considered when evaluating the suitability of an infiltration trench for a development site.

Table 6.12.1. Infiltration Trench Constraints

Contributing Drainage Area	Flow-Splitter	High Loading Situations	Hotspot Land Uses	Irrigation or Baseflow
5 acres max.	Off-line configuration allows flows greater than T_v to be diverted to other GIPs with flow splitter.	Not intended to treat sites with high sediment or trash/debris loads.	Generally, not allowed, refer to Appendix D.	Continuous flow from groundwater, sump pumps, or other sources not permitted.
Location	Restrictive Layers	Setbacks	Soils Requirement	Water Table Requirement
Locate in an open or lawn area, with the top of the structure close to the ground. Not permitted under pavement.	Clay lenses, bedrock, or other restrictive layers below the bottom of the trench will reduce infiltration rates unless excavated.	Private wells require 100'. Public wells require 1,200'. Septic systems require 100'. Property lines require 10'. Building foundations require 25'. Surface waters require 100'. Surface drinking water sources require 400' (100' for a tributary).	HSG C or D need an underdrain.	2' of separation

The data listed below is necessary for the design of an infiltration trench and shall be included with the development plan. See Appendix B for more information on required elements for the storm water management plan.

- Existing and proposed site, topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- If no underdrain is proposed for the infiltration area, then infiltration testing of native soils at proposed elevation of bottom of infiltration area is required. See Appendix E for more information.
- If no underdrain is proposed, then the Infiltration Feasibility form provided in Appendix B shall be submitted with the SWMP.

6.12.3 Design Requirements

The major design goal for infiltration trenches is to maximize runoff volume reduction and pollutant removal. To this end, designers may choose to go with the baseline design (Level 1 (**RR 43**)) or choose an enhanced design (Level 2 (**RR 89**)) that maximizes pollutant and runoff reduction. Design criteria for Level 1 and Level 2 infiltration trenches are summarized in **Table 6.12.2**. Typical details are located in Appendix F.

Table 6.12.2. Infiltration Trench Design Criteria

Level 1 Design (RR 43)	Level 2 Design (RR: 89)
Sizing: Tv = [1(Rv)(A)/12] – the volume reduced by an upstream GIP	Sizing: Tv = [1.1(Rv)(A)/12] – the volume reduced by an upstream GIP
At least two forms of pre-treatment (see Table 6.12.3)	At least three forms of pre-treatment (see Table 6.12.3)
Soil infiltration rate > 0.5 in/hr and <1 in/hr 1 test hole/50 linear ft, minimum of 2 (see Appendix E)	Soil infiltration rates of 1.0 to 4.0 in/hr 1 test hole/50 linear ft, minimum of 2 (see Appendix E)
Minimum of 2 feet between the bottom of the infiltration practice	Minimum of 2 feet between the bottom of the infiltration practice
T_v infiltrates within 48 hours	T_v infiltrates within 48 hours
Minimum setbacks – see setbacks (Table 6.12.1)	Minimum setbacks – see setbacks (Table 6.12.1)
All Designs are subject to hotspot runoff restrictions/prohibitions	All Designs are subject to hotspot runoff restrictions/prohibitions

A well-designed infiltration trench consists of:

- Excavated shallow trench backfilled with sand, coarse stone, and pea gravel and lined with a filter fabric;
- Appropriate pretreatment measures; and
- One or more observation wells to show how quickly the trench dewaters or to determine if the device is clogged.

Sizing of Infiltration Trenches

Storm Water Quality

The storage volume (T_v) shall be contained in the gravel trench.

Equation 1. Treatment Volume

$$T_V = P \times Rv \times A/12$$

Where:

T_V = Storage Volume, cu ft
P = The rainfall depth for Treatment Volume, 1 in (Level 1) or 1.1 in (Level 2)
Rv = Runoff coefficient from RR Method (See Chapter 3)
A = Site area, sq. ft.

Flows above the T_V flow rate (Q_{TV}) shall be diverted to other GIPs.

Flows exceeding the Tv flow are to be diverted from the trench. Flows can be calculated using the Rational Method:

Equation 2. Rational Method for Treatment Volume Flow Rate

$$Q_{TV} = CIA$$

Where:

Q_{TV} = The Tv flow rate
C = Runoff coefficient
I = Rainfall intensity for the design storm and a duration equal to the time of concentration (see Chapter 4 for more detail)
A = The contributing drainage area for the GIP, in acres

A flow regulator (or flow splitter diversion structure) shall be supplied to divert the Tv to the infiltration trench. Size low flow orifice, weir, or other device to pass Q_{TV}.

The area of the trench can be determined from the following equation:

Equation 3. Surface Area for Infiltration Trench

$$S = \frac{T_V}{0.4(D)}$$

Where:

SA = Surface Area (sq. ft.)
Tv = Total volume to be infiltrated (cu. ft.)
D = Media depth of trench (ft.)

All infiltration systems shall be designed to fully dewater the entire Tv within 24 to 48 hours after the rainfall event.

Size pretreatment facility to treat 25% of the water quality volume (Tv) for offline configurations.

See the Pretreatment/Inlets Section for more details. Adequate storm water outfalls shall be provided for the overflow exceeding the capacity of the trench, ensuring nonerosive velocities on the down-slope.

Soil Infiltration Rate Testing

The infiltration rate of subsoils at the invert elevation of the infiltration trench shall exceed 0.5 inch per hour. On-site soil infiltration rate testing procedures are outlined in Appendix E. The number of soil tests varies base on the size of the bioretention area:

- < 1,000 ft^2 = 2 tests
- 1,000 – 10,000 ft^2 = 4 tests
- >10,000 ft^2 = 4 tests + 1 test for every additional 5,000 ft^2

Pre-Treatment

Pre-treatment of runoff entering infiltration trenches is necessary to trap coarse sediment particles before they cause clogging. Several pre-treatment measures are feasible, depending on the scale of the infiltration practice and whether it receives sheet flow, shallow concentrated flow, or deeper concentrated flows. A low-flow diversion or flow splitter can be used at the inlet to allow only the Treatment Volume to enter the facility. This may be achieved with a weir or curb opening sized for the target flow, in combination with a bypass channel. Using a weir or curb opening helps minimize clogging and reduces the maintenance frequency. The following are appropriate pretreatment options and additional information is also included in Chapter 6, Section 2.

- For a trench receiving sheet flow from an adjacent drainage area, the pretreatment system shall consist of a vegetated filter strip with a minimum 25-foot length. A vegetated buffer strip around the entire trench is required if the facility is receiving runoff from both directions. If the infiltration rate for the underlying soils is greater than 2 inches per hour, 50% of the Tv shall be pretreated by another method prior to reaching the infiltration trench.
- For an off-line configuration, pretreatment shall consist of a sediment forebay, vault, plunge pool, or similar sedimentation chamber (with energy dissipaters) sized to 25% of the storage volume (Tv). Exit velocities from the pretreatment chamber shall be nonerosive for the 2-year design storm.
- Every infiltration practice shall include multiple pretreatment techniques, although the nature of pretreatment practices depends on the scale at which infiltration is applied. The number, volume, and type of acceptable pretreatment techniques needed for the two scales of infiltration are provided in **Table 6.12.3.**

Table 6.12.3. Required Pretreatment Elements for Infiltration Practices

Pretreatment[1]	Scale of Infiltration	
	Small-Scale Infiltration	Conventional Infiltration
Number and Volume of Pretreatment Techniques Employed	2 techniques; 15% minimum pretreatment volume required (inclusive).	3 techniques; 25% minimum pretreatment volume required (inclusive); at least one separate pre-treatment cell.
Acceptable Pretreatment Techniques	Grass filter strip, Grass channel, Plunge pool, Gravel diaphragm	Sediment trap cell, Sand filter cell, Sump pit, Grass filter strip, Gravel diaphragm

1 A minimum of 50% of the runoff reduction volume shall be pre-treated by a filtering or bioretention practice prior to infiltration if the site is a restricted storm water hotspot.

Infiltration Trench Material Specifications

Infiltration trenches shall have the following physical specifications/geometry:

- The required storage volume in the gravel trench is equal to the water quality volume (Tv).
- A trench shall be designed to fully dewater the entire Tv within 24 to 48 hours after a rainfall event. The slowest infiltration rate obtained from tests performed at the site shall be used in the design calculations.
- Trench depths shall be between 3 and 8 feet to provide for easier maintenance. The width of a trench shall be less than 25 feet.
- Broader, shallow trenches reduce the risk of clogging by spreading the flow over a larger area for infiltration.
- The surface area required is calculated based on the trench depth, soil infiltration rate, aggregate void space, and fill time (assume a fill time of 2 hours for most designs).
- The bottom slope of a trench shall be flat across its length and width to evenly distribute flows, encourage uniform infiltration through the bottom, and reduce the risk of clogging.
- The stone aggregate used in the trench shall be washed, bank-run gravel, 1.5 to 2.5 inches in diameter with a void space of about 40%. Aggregate contaminated with soil shall not be used. A porosity value (void space/total volume) of 0.32 shall be used in calculations unless aggregate specific data exist.
- A 6-inch layer of clean, washed sand is placed on the bottom of the trench to encourage drainage and prevent compaction of the native soil while the stone aggregate is added.
- The infiltration trench is lined on the sides and top by an appropriate geotextile filter fabric that prevents soil piping but has greater permeability than the parent soil. The top layer of filter fabric is located 2 to 6 inches from the top of the trench and serves to prevent sediment from passing into the stone aggregate. Since this top layer serves as a sediment barrier, it will need to be replaced more frequently and shall be readily separated from the side sections.
- The top surface of the infiltration trench above the filter fabric is typically covered with pea gravel. The pea gravel layer improves sediment filtering and maximizes the pollutant removal in the top of the trench. In addition, it can easily be removed and replaced shall the device begin to clog. Alternatively, the trench can be covered with permeable topsoil and planted with grass in a landscaped area.
- An observation well shall be installed in every infiltration trench and shall consist of a perforated PVC or HDPE pipe, 4 to 6 inches in diameter, extending to the bottom of the trench. The observation well will show the rate of dewatering after a storm, as well as provide a means of determining sediment levels at the bottom and when the filter fabric at the top is clogged and maintenance is needed. It shall be installed along the centerline of the structure, flush with the ground elevation of the trench. A visible floating marker shall be provided to indicate the water level. The top of the well shall be capped and locked to discourage vandalism and tampering.
- The trench excavation shall be limited to the width and depth specified in the design. Excavated material shall be placed away from the open trench so as not to jeopardize the stability of the trench sidewalls. The bottom of the excavated trench shall not be loaded in a way that causes soil compaction and shall be

scarified prior to placement of sand. The sides of the trench shall be trimmed of all large roots. The sidewalls shall be uniform with no voids and scarified prior to backfilling. All infiltration trench facilities shall be protected during site construction and shall be constructed after upstream areas have been stabilized.

Other design criteria for infiltration trenches include the following:

- **Outlet Structures**. Outlet structures are not required for infiltration trenches.
- **Emergency Spillway**. Typically for off-line designs, there is no need for an emergency spillway. However, a nonerosive overflow channel shall be provided to safely pass flows that exceed the storage capacity of the trench to a stabilized downstream area or watercourse.
- **Maintenance Access**. Adequate access in an easement shall be provided to an infiltration trench facility for inspection and maintenance.
- **Safety Features**. In general, infiltration trenches are not likely to pose a physical threat to the public and do not need to be fenced.
- **Landscaping**. Vegetated filter strips and buffers shall fit into and blend with surrounding area. Native grasses are preferable, if compatible. The trench may be covered with permeable topsoil and planted with grass in a landscaped area.
- **Additional Site-Specific Design Criteria and Issues**. Not suitable for karst areas without adequate geotechnical testing.
- **Additional Permitting Requirements**. Underground Injection Control Permit (UIC) may be required from the State of Alabama if the trench is deeper than its widest surface dimension.

6.12.4 Construction, Protection, and Maintenance Requirements

All GIPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all GIPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For City policies, additional guidance, and forms pertaining to GIP protection, inspection and maintenance requirements, see Appendix B of this manual.

Requirements During Construction

- Construction equipment shall be restricted from the infiltration area to prevent compaction of native soils.
- A dense and vigorous vegetative cover, or other effective soil stabilization practice, shall be established over the contributing pervious drainage areas before storm water can be accepted into the infiltration trench. This will prevent sediment from clogging the infiltration area.
- Areas where GIPs will be located shall be readily identifiable and protected from unwanted encroachments during construction, both on development plans and at the construction site. Physical protection measures can include, but are not limited to, orange fencing, wood or chain link fencing, and signage. For infiltration-based practices, protection of GIP locations during construction of a land development will ensure that native soils that surround (or are within) the storm water treatment area will remain un-compacted and, therefore, continue to meet the design parameters that were specified in the approved development plan. For other practices, such as extended detention ponds, protection of GIP locations can reduce the soil compaction that typically occurs during construction, which often leads to poor soil conditions for plant growth once the GIP shall be permanently stabilized. Regardless, a lack of GIP protection will most certainly reduce or destroy the storm water functionality of the GIP once it is installed, often leading to costly corrective actions required by the City.

Protection Requirements

- Provide signage for the GIP
    - Allows for easy identification and location of the GIP.

- Serves as a general education tool, making those responsible for property, landscape or GIP maintenance, and the general public aware of the water quality features of the GIP and to avoid encroachment.
- Consider using natural fencing such as graduated vegetation sizes and densities, dense shrub fencing, rocks, or other landscape features placed in a manner that discourages foot, equipment, and vehicle traffic in the storm water treatment area.

❖ Design the layout of the infiltration area such that maintenance access can be achieved without the need for vehicles or equipment in the storm water treatment area.

❖ Provide clearly marked, easily accessible and well-maintained driveways, sidewalks, and pedestrian pathways that lead vehicles, equipment, and foot traffic around the storm water treatment areas.

Inspection Requirements

❖ Inspect the areas where storm water flows into or out of the infiltration trench for clogging or sediment buildup.

❖ Inspect trees, shrubs, and other vegetation to ensure they meet landscaping and vegetation specifications. Replace if necessary.

❖ Inspect the property that drains to the infiltration trench for erosion, exposed soil, or stockpiles of other potential pollutants.

Maintenance Requirements

❖ Perform weeding, pruning, and trash removal as needed to maintain appearance.

❖ Inspect vegetation to evaluate health, replace if necessary.

❖ Keep inlets clear of debris to prevent clogging, clear if necessary.

❖ Inspect infiltration area for sediment build up, erosion, vegetative health/conditions, etc. perform appropriate maintenance as necessary.

❖ Inspect observation well. Clean or replace clogged aggregate if necessary.

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6.13 Cisterns

Figure 6.13.1. Cistern at Stewart Perry Construction, Birmingham, AL

DEVELOPMENT ATTRIBUTES

Construction Cost	LOW
Operation and Maintenance Cost	MODERATE
Ground-Level Encroachment	HIGH
Building Footprint Enhancement	LOW
Triple Bottom-Line Benefits	MODERATE

Storage Reuse

Description:

Rain tanks and cisterns are used to intercept, divert, store, and release rain falling on rooftops for future use.

Variations:

- Aboveground Storage
- Underground Storage

Key Advantages:

- Water source for non-potable uses (toilet flushing, irrigation)
- Flexible to site conditions
- Aboveground cisterns relatively easy to install and maintain
- Reduces storm water runoff volume and peak discharge rate through retention
- Reduces pollutant loads

Key Limitations:

- Systems shall drain between storm events
- Water source for non-potable uses only
- Freight charges can be costly for large cistern purchases
- Reduction in runoff volume and peak discharge dependent on amount of storage available
- Must be childproof and sealed against mosquitos

PERFORMANCE STANDARD COMPLIANCE					
Water Quality			Stream Channel Protection	Overbank Flood Protection	Extreme Flood Protection
Treatment Volume		80% TSS Removal			
Level 1	Level 2				
Design Dependent			▶	▶	▶

✓ Suitable for this practice

▶ Provides partial benefits

6.13.1 General Application

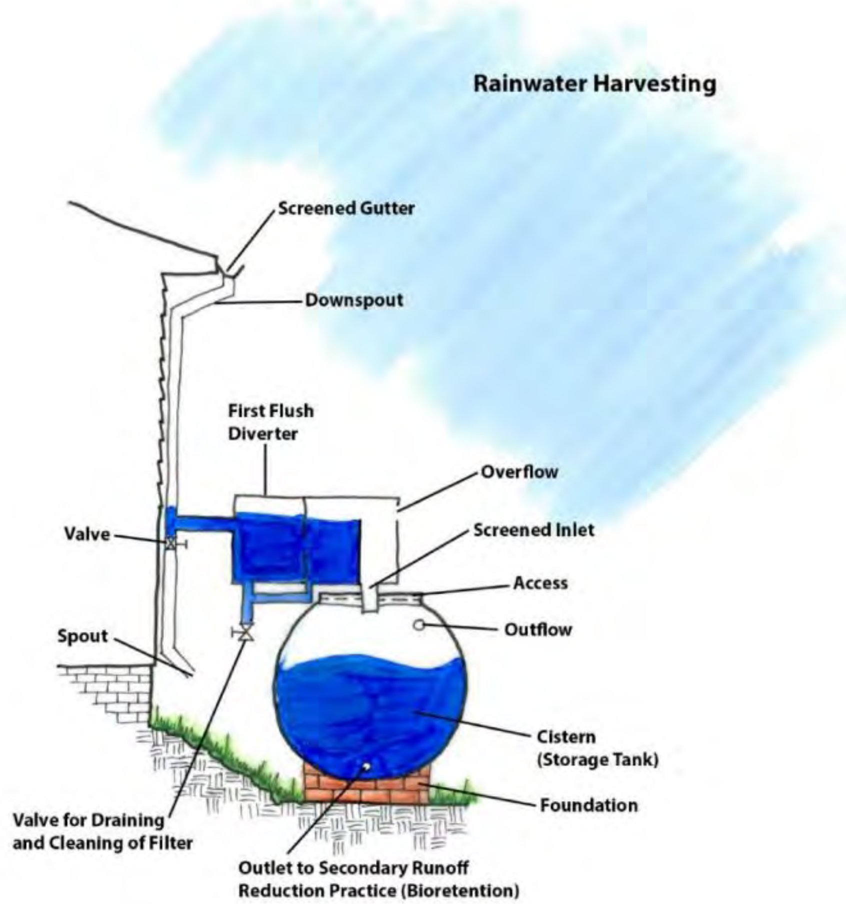
A cistern intercepts, diverts, stores, and releases rainfall for future use. The term cistern is used in this specification, but it is also known as a rainwater harvesting system. Rainwater that falls on a rooftop is collected and conveyed into an above- or below-ground storage tank where it can be used for non-potable water uses and on-site storm water disposal/infiltration. Non-potable uses may include flushing of toilets and urinals inside buildings, landscape irrigation, exterior washing (e.g., car washes, building facades, sidewalks, street sweepers, fire trucks, etc.), supply for chilled water-cooling towers, replenishing and operation of laundry, if approved by the City.

Figure 6.13.2. Cistern at Jones Valley Urban Farm, Birmingham, AL

In many instances, rainwater harvesting can be combined with a secondary (down-gradient) runoff reduction practice to enhance runoff volume reduction rates and/or provide treatment of overflow from the rainwater harvesting system. Chapter 4 provides more detail on system configurations, including the use of secondary practices.

Some candidate secondary practices include:

- Downspout Disconnection: Chapter 6, Section 6 (excluding rain tanks and cisterns). This may include release to a compost-amended filter path
- Sheet Flow: Chapter 6, Section 8
- Grass Channel/Open Channel: Chapter 6, Section 7
- Infiltration: Chapter 6, Section 12
- Bioretention: Chapter 6, Section 3
- Urban Bioretention: Chapter 6, Section 4. Storage and release in a foundation planter.
- Dry Water Quality Swale/Enhanced Swale: Chapter 6, Section 5



In addition, the actual runoff reduction rates for rainwater harvesting systems are "user defined" based on tank size, configuration, demand drawdown, and use of secondary practices.

Additional considerations for use of cisterns on a development site include the following:

Roof Surface

The rooftop shall be made of smooth, non-porous material with efficient drainage either from a sloped roof or an efficient roof drain system.

Collection and Conveyance System

- ❖ Gutters and downspouts shall be designed as they would for a building without a rainwater harvesting system.
- ❖ Gutters shall be sized with slopes specified to contain the necessary amount of storm water for treatment volume credit.
- ❖ Pipes (connecting downspouts to the cistern tank) shall be at a minimum slope of 1.5% and sized/designed to convey the intended design storm.

Pre-Screening and First Flush Diverter

- ❖ Inflow shall be pre-screened to remove leaves, sediment, and other debris.
- ❖ For large systems, the first flush (0.02 – 0.06 inches) of rooftop runoff shall be diverted to a secondary treatment practice to prevent sediment from entering the system.
- ❖ Rooftop runoff shall be filtered to remove sediment before it is stored.

Storage Tank

Storage tanks are sized based on consideration of indoor and outdoor water demand, long-term rainfall, and rooftop capture area.

Distribution System

- ❖ The rainwater harvesting system shall be equipped with an appropriately-sized pump that produces sufficient pressure for all end-uses.
- ❖ Distribution lines shall be installed with shutoff valves and cleanouts and shall be buried beneath the frost line or insulated to prevent freezing.

Overflow

- ❖ The system shall be designed with an overflow mechanism to divert runoff when the storage tanks are full.
- ❖ Overflows shall discharge to pervious areas set back from buildings and paved surfaces or to secondary GIPs.

6.13.2 Planning and Physical Feasibility

A number of site-specific features influence how cisterns are designed and/or utilized. These should not be considered comprehensive, and the planning process shall incorporate rainwater harvesting systems into the site design. The following criteria provided it **Table 6.13.1** shall be considered when evaluating the suitability of a cistern for a development site.

Table 6.13.1. Cistern Constraints

Available Space	Building Rooftops	Contributing Drainage Area	Hotspot Land Uses	Hydraulic Head Needed	Rainwater Quality
Adequate space is needed to house the tank and any overflow. Cisterns can be underground, indoors, on rooftops or within buildings that are structurally designed to support the added weight, and adjacent to buildings.	Not permitted where roof material contains asbestos/trace metals/toxic compounds (asphalt sealcoats, tar and gravel, painted roofs, galvanized metal roofs, sheet metal). Sealant or paint roof surface shall be certified for rainwater harvesting by the National Sanitation Foundation (ANSI/NSF standard).	Rooftop drainage only. Use sizing guidelines in this design specification.	Effective GIP to prevent roof runoff from contacting ground-level hotspots. Not allowed for industrial rooftops designated as hotspots.	Cistern shall be up-gradient of intended use or use a pump.	Low rainwater pH may result in rooftop, tank lining, or water lateral metal leaching. Limestone or other materials may need to be added in the tank to buffer acidity.
Setbacks	Soils Requirement	Topography	Utility Requirement	Water Table Requirement	
Building foundations require 10 feet for cistern itself and areas that will be saturated by overflows. Not permitted in areas with vehicle traffic or vehicles loads. Cisterns shall be watertight.	Sufficient bearing capacity of native soil or aggregate/concrete base required. Geotechnical test required.	Requires sufficient drop from downspout leaders to the final mechanism receiving gravity-fed discharge and/or overflow.	Consider clearance for all utilities.	Sufficient fasteners/weights to prevent buoyancy. Refer to manufacturer's specifications.	

The data listed below is necessary for the design of a cistern and shall be included with the development plan. See Appendix B for more information on required elements for the development plan.

- Existing and proposed site, topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Water surface elevation of nearby water systems as well as the depth to seasonally high groundwater.
- Infiltration testing and geotechnical testing of native soils at proposed elevation of bottom of cistern.

Storm Water Uses

The capture and reuse of rainwater can significantly reduce storm water runoff volumes and pollutant loads. By providing a reliable and renewable source of water to end users, rainwater harvesting systems can also have environmental and economic benefits beyond storm water management (e.g., increased water conservation, water supply during drought and mandatory municipal water supply restrictions, decreased demand on municipal or groundwater supply, decreased water costs for the end-user, potential for increased groundwater recharge, etc.). To enhance their runoff reduction and nutrient removal capability, rainwater harvesting systems can be combined with other rooftop disconnection practices, such as infiltration and bioretention or foundation planters. In this specification, these allied practices are referred to as "secondary runoff reduction practices." While the most common uses of captured rainwater are for non-potable purposes, such as those noted above, in some limited cases rainwater can be treated to potable standards. This is not permitted in Birmingham at this time.

Design Objectives and System Configurations

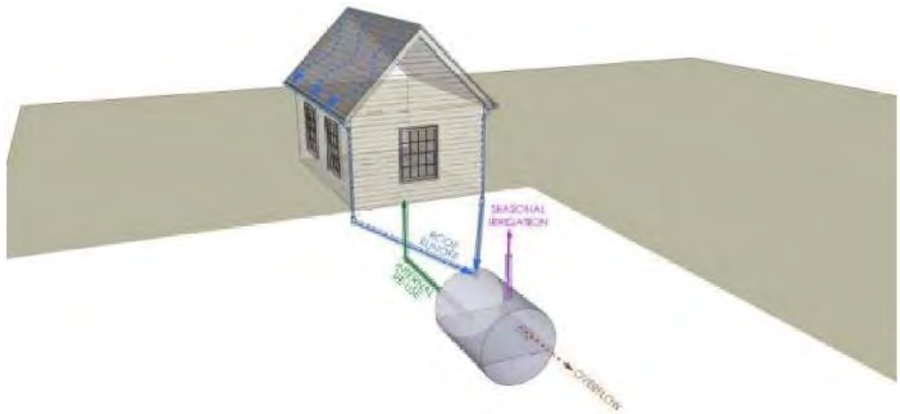
Many rainwater harvesting system variations can be designed to meet user demand and storm water objectives. This specification focuses on providing a design framework for addressing the Treatment Volume (T_v) objectives. From a rainwater harvesting standpoint, there are numerous potential configurations that could be implemented. However, in terms of the goal of addressing the design treatment volume, this specification adheres to the following concepts in order to properly meet the storm water volume reduction goals:

- Credit is only available for dedicated year-round drawdown/demand for the water. While seasonal practices (such as irrigation) may be incorporated into the site design, they are not considered to contribute to the treatment volume credit (for storm water purposes) unless a drawdown at an equal or greater rate is also realized during non-seasonal periods (e.g. treatment in a secondary runoff reduction practice during non-irrigation months).
- System design is encouraged to use rainwater as a resource to meet on-site demand or in conjunction with other runoff reduction practices (especially those that promote groundwater recharge).
- Pollutant load reduction is realized through reduction of the volume of runoff leaving the site.
- Peak flow reduction is realized through reduced volume and temporary storage of runoff.

Therefore, the rainwater harvesting system design configurations presented in this specification are targeted for continuous (year-round) use of rainwater through (1) internal use and (2) irrigation and/or treatment in a secondary practice. Three basic system configurations are described below.

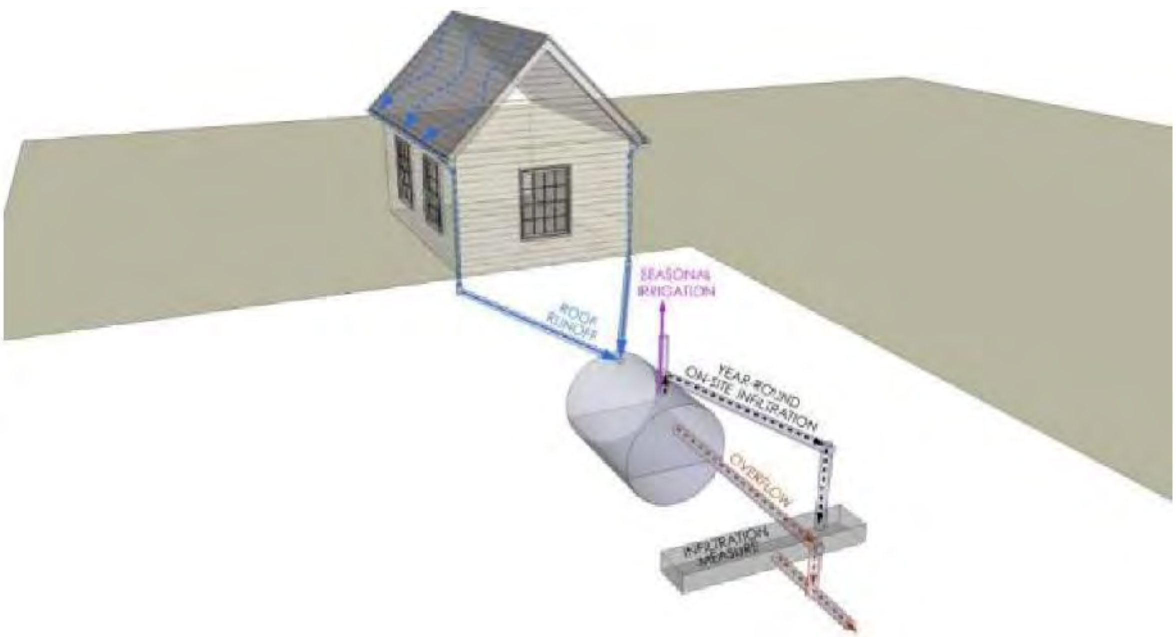
Configuration 1: Year-round indoor use with optional seasonal outdoor use (Figure 6.13.3). The first configuration is for year-round indoor use along with optional seasonal outdoor use, such as irrigation. Because there is no on-site secondary runoff reduction practice incorporated into the design for non-seasonal (or non-irrigation) months, the system shall be designed and treatment volume awarded for the interior use only. (However, it should be noted that the seasonal irrigation will provide an economic benefit in terms of water usage.) Storm water credit can be enhanced by adding a secondary runoff reduction practice (see Configuration 3 below).

Figure 6.13.3. Configuration 1: Year-Round Indoor Use with Optional Seasonal Outdoor Use *(Source: VADCR, 2011)*



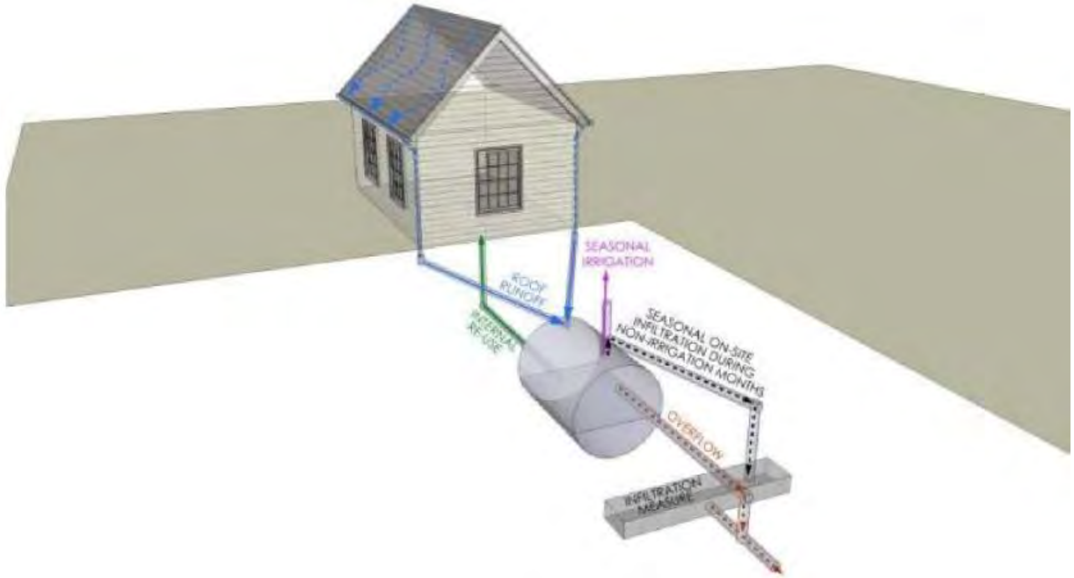
Configuration 2: Seasonal outdoor use and approved year-round secondary runoff reduction practice (Figure 6.13.4). The second configuration uses stored rainwater to meet a seasonal or intermittent water use, such as irrigation. However, because these uses are only intermittent or seasonal, this configuration also relies on an approved secondary practice for storm water credit. Compared to a stand-alone GIP (without the upgradient tank), the size and/or storage volume of the secondary practice can be reduced based on the storage in the tank. The tank's drawdown and release rate shall be designed based on the infiltration properties, surface area, and capacity of the receiving secondary runoff reduction practice. The release rate therefore is typically much less than the flow rate that would result from routing a detention facility. The secondary practice shall serve as a "backup" facility, especially during non-irrigation months. In this regard, the tank shall provide some meaningful level of storage and reuse, accompanied by a small flow to the secondary practice. This is especially important if the size and/or storage volume of the secondary practice is reduced compared to using that practice in a "stand-alone" design (i.e., without an upgradient cistern). See tank design 3 below for more information.

Figure 6.13.4. Configuration 2: Seasonal Outdoor Use and Approved Year-Round Secondary Practice *(Source: VADCR, 2011)*



Configuration 3: Year-round indoor use, seasonal outdoor irrigation, and non-seasonal treatment in a secondary runoff reduction practice (Figure 6.13.5). The third configuration provides for a year-round internal non-potable water demand and a seasonal outdoor, automated irrigation system demand. In addition, this configuration incorporates a secondary practice during non-irrigation (or non-seasonal) months in order to yield a greater storm water credit. In this case, the drawdown due to seasonal irrigation shall be compared to the drawdown due to water released to the secondary practice. The minimum of these two values is used for system modeling and storm water credit purposes.

Figure 6.13.5. Configuration 3: Year-Round Indoor Use, Seasonal Outdoor Irrigation, and Non-Seasonal On-Site Treatment in Secondary Practice *(Source: VADCR, 2011)*

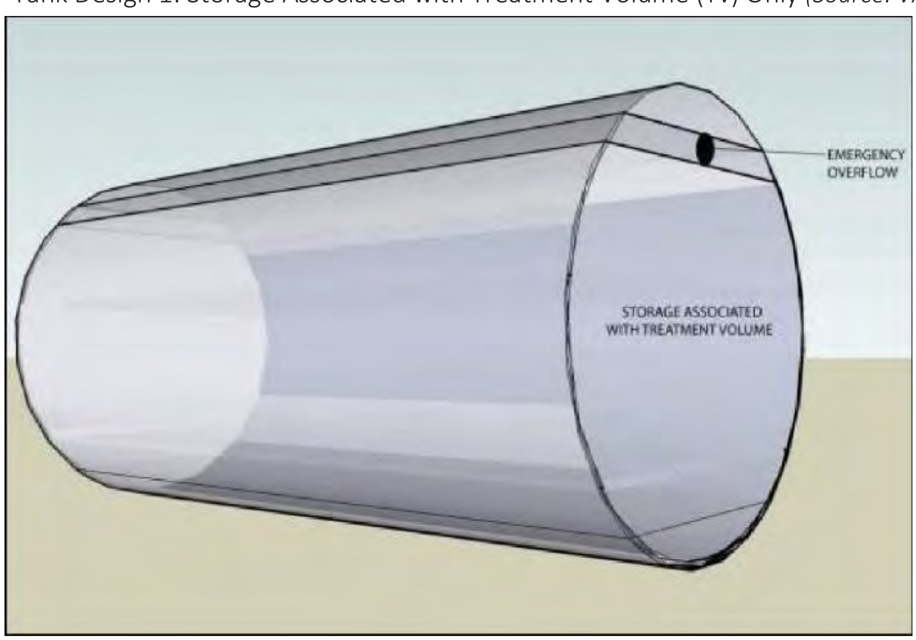


Design Objectives and Tank Design Set-Ups

Pre-fabricated rainwater harvesting cisterns typically range in size from 250 to over 30,000 gallons. There are three basic tank design configurations used to meet the various rainwater harvesting system configurations that are described above.

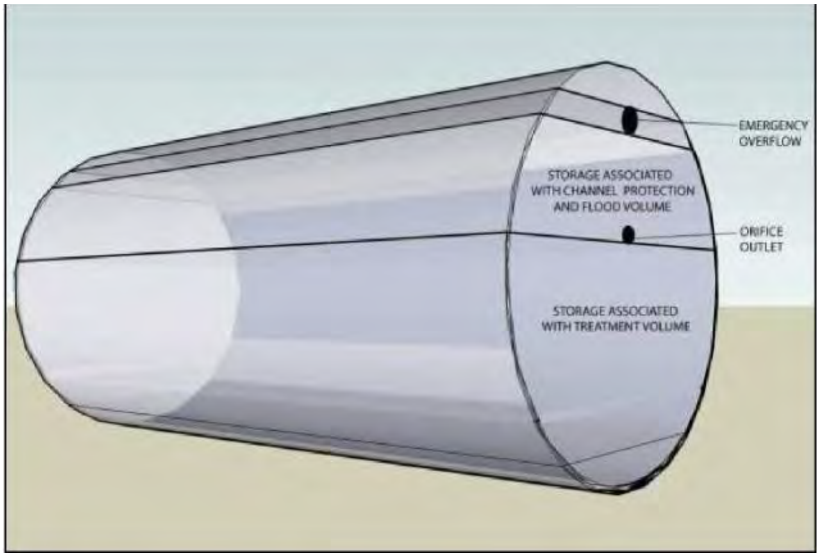
Tank Design 1. The first tank set-up (**Figure 6.13.6**) maximizes the available storage volume associated with the Treatment Volume (T_v) to meet the desired level of treatment credit. This layout also maximizes the storage that can be used to meet a demand. An emergency overflow exists near the top of the tank as the only gravity release outlet device (not including the pump, manway or inlets). It should be noted that it is possible to address channel and flood protection volumes with this tank configuration, but the primary purpose is to address T_v.

Figure 6.13.6. Tank Design 1: Storage Associated with Treatment Volume (Tv) Only *(Source: VADCR, 2011)*



Tank Design 2. The second tank set-up (**Figure 6.13.7**) uses tank storage to meet the Treatment Volume (T_v) objectives as well as using an additional detention volume above the treatment volume space to also meet some, or all, of the channel and/or flood protection volume requirements. An orifice outlet is provided at the top of the design storage for the T_v storage level, and an emergency overflow is located at the top of the detention volume level. This specification only addresses the storage for the T_v. However, it may be possible to model and size the Channel Protection and Flood Protection (detention) volumes.

Figure 6.13.7. Tank Design 2: Storage Associated with Treatment, Channel Protection and Flood Volume *(Source: VADCR, 2011)*

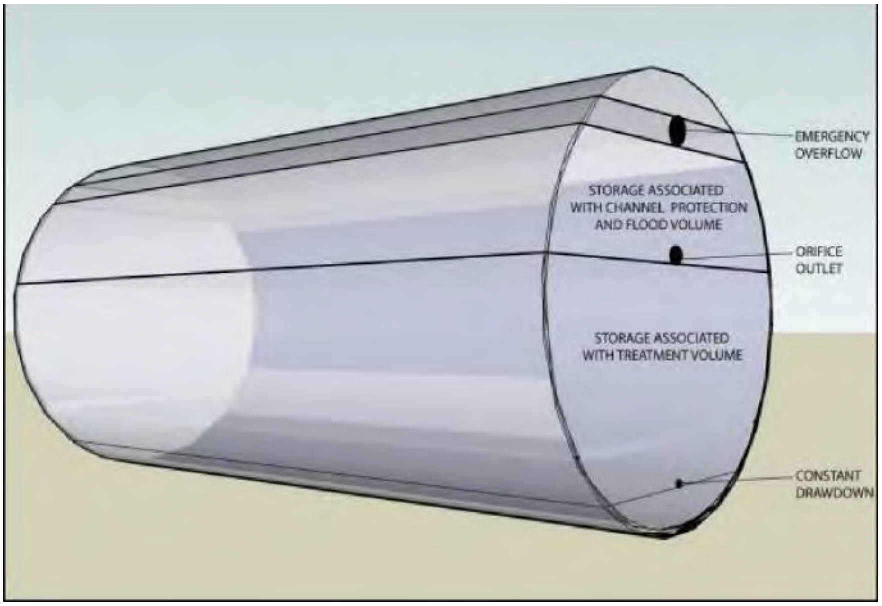


Tank Design 3. The third tank set-up (**Figure 6.13.8**) creates a constant drawdown within the system. The small orifice at the bottom of the tank needs to be routed to an appropriately designed secondary practice (e.g., rain garden, micro-scale infiltration, urban bioretention, etc.) that will allow the rainwater to be treated and allow for groundwater recharge over time. The release shall not be discharged to a receiving channel or storm drain without treatment and maximum specified drawdown rates from this constant drawdown shall be adhered to, since the primary function of the system is not intended to be detention.

For the purposes of this tank design, the secondary practice shall be considered a component of the rainwater harvesting system with regard to the runoff reduction percentage. In other words, the runoff reduction associated with the secondary practice shall not be added (or double-counted) to the rainwater harvesting percentage. The reason for this is that the secondary practice is an integral part of a rainwater harvesting system with a constant drawdown. The exception to this would be if the secondary practice were also sized to capture and treat impervious area beyond the area treated by rainwater harvesting (for instance, the adjacent yard or a driveway). In this case, only these additional areas shall be added to receive credit for the secondary practice.

While a small orifice is shown at the bottom of the tank in Figure 6.13.8, the orifice could be replaced with a pump that would serve the same purpose, conveying a limited amount of water to a secondary practice on a routine basis.

Figure 6.13.8. Tank Design 3: Constant Drawdown, Storage Associated with Treatment, Channel Protection and Flood Volume *(Source: VADCR, 2011)*



On-Site Treatment in a Secondary Practice

Recent rainwater harvesting system design materials do not include guidance for on-site storm water infiltration or "disposal". The basic approach is to provide a dedicated secondary runoff reduction practice on-site that will ensure water within the tank will gradually drawdown at a specified design rate between storm events. Secondary runoff reduction practices may include the following:

- Downspout Disconnection, excluding rain tanks and cisterns. This may include release to a compost-amended filter path.
- Sheet Flow
- Grass Channel/Open Channel
- Infiltration
- Bioretention
- Urban Bioretention. Storage and release in foundation planter.
- Dry Water Quality Swale/Enhanced Swale

The secondary practice approach is useful to help achieve the desired treatment volume when demand is not enough to sufficiently draw water levels in the tank down between storm events. Of course, if demand for the harvested rainwater is relatively high, then a secondary practice may not be needed or desired.

Use of a secondary practice may be particularly beneficial to employ in sites that use captured rainwater for irrigation during part of the year but have no other use for the water during non-irrigation months. During non-irrigation months, credit cannot be realized unless on-site infiltration/treatment or another drawdown mechanism creates a year-round drawdown, since no storm water benefit would be realized during non-seasonal periods.

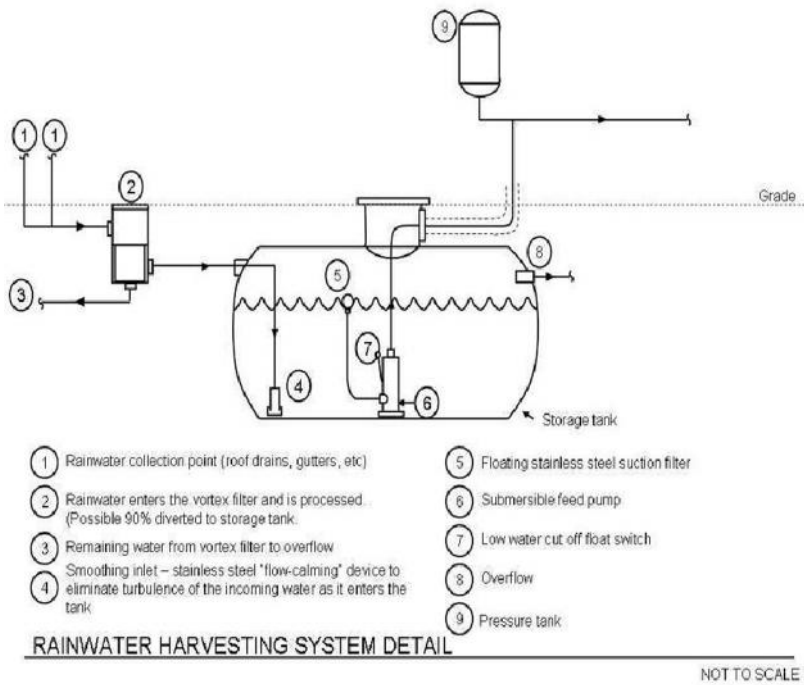
The design of the secondary practice shall account for soil types, ground surface areas, release rates, methods of conveyance (gravity fed or pumped), time periods of operation, and invert elevations to determine the disposal rate and sizing of the practice (both storage volume and surface area).

System Components

There are six primary components of a rainwater harvesting system (**Figure 6.13.9**):

- Roof surface
- Collection and conveyance system (e.g. gutter and downspouts)
- Pre-screening and first flush diverter
- Storage tank
- Distribution system
- Overflow, filter path, or secondary runoff reduction practice

Figure 6.13.9. Sample Rainwater Harvesting System Detail *(Source: VADCR, 2011)*



Each of these system components is discussed below:

- **Rooftop Surface.** The rooftop shall be made of smooth, non-porous material with efficient drainage either from a sloped roof or an efficient roof drain system. Slow drainage of the roof leads to poor rinsing and a prolonged first flush, which can decrease water quality. If the harvested rainwater is selected for uses with significant human exposure (e.g., pool filling, watering vegetable gardens), care shall be taken in the choice of roof materials. Some materials may leach toxic chemicals making the water unsafe for humans.

- **Collection and Conveyance System.** The collection and conveyance system consist of the gutters, downspouts, and pipes that channel storm water runoff into storage tanks. Gutters and downspouts shall be designed as they would for a building without a rainwater harvesting system. Aluminum, round-bottom gutters and round downspouts are generally recommended for rainwater harvesting. Minimum slopes of gutters shall be specified. At a minimum, gutters shall be sized with slopes specified to contain the 1-inch storm at a rate of 1-inch/hour for treatment volume credit. If volume credit will also be sought for channel and flood protection, the gutters shall be designed to convey the 2 and 10-year storm, using the appropriate 2- and 10-year storm intensities, specifying size and minimum slope. In all cases, gutters shall be hung at a minimum of 0.5% for 2/3 of the length and at 1% for the remaining 1/3 of the length.

Pipes (connecting downspouts to the cistern tank) shall be at a minimum slope of 1.5% and sized/designed to convey the intended design storm, as specified above. In some cases, a steeper slope and larger sizes may be recommended and/or necessary to convey the required runoff, depending on the design objective and design storm intensity. Gutters and downspouts shall be kept clean and free of debris and rust.

- **Pre-Treatment: Screening, First Flush Diverters and Filter Efficiencies.** Pre-filtration is required to keep sediment, leaves, contaminants, and other debris from the system. Leaf screens and gutter guards meet the minimal requirement for pre-filtration of small systems, although direct water filtration is preferred. All pre-filtration devices shall be low-maintenance or maintenance-free. The purpose of pre-filtration is to significantly cut down on maintenance by preventing organic buildup in the tank, thereby decreasing microbial food sources.

  For larger tank systems, the initial first flush shall be diverted from the system before rainwater enters the storage tank. Designers should note that the term "first flush" in rainwater harvesting design does not have the same meaning as has been applied historically in the design of storm water treatment practices. In this specification, the term "first flush diversion" is used to distinguish it from the traditional storm water management term "first flush". The amount can range between the first 0.02 to 0.06 inches of rooftop runoff. The diverted flows (first flush diversion and overflow from the filter) shall be directed to an acceptable pervious flow path that will not cause erosion during a 2-year storm or to an appropriate GIP on the property for infiltration. Preferably the diversion will be conveyed to the same secondary runoff reduction practice that is used to receive tank overflows.

  Various first flush diverters are described below. In addition to the initial first flush diversion, filters have an associated efficiency curve that estimates the percentage of rooftop runoff that will be conveyed through the filter to the storage tank. If filters are not sized properly, a large portion of the rooftop runoff may be diverted and not conveyed to the tank at all. A design intensity of 1 inch/hour shall be used for the purposes of sizing pre-tank conveyance and filter components. This design intensity captures a significant portion of the total rainfall during a large majority of rainfall events (NOAA 2004). If the system will be used for channel and flood protection, the 2- and 10-year storm intensities shall be used for the design of the conveyance and pre-treatment portion of the system. For the 1-inch storm treatment volume, a minimum of 95% filter efficiency is required. This efficiency includes the first flush diversion. For the 2- and 10-year storms, a minimum filter efficiency of 90% shall be met.

  - **First Flush Diverters.** First flush diverters direct the initial pulse of storm water runoff away from the storage tank. While leaf screens effectively remove larger debris such as leaves, twigs, and blooms from harvested rainwater, first flush diverters can be used to remove smaller contaminants such as dust, pollen, and bird and rodent feces (**Figure 6.13.10**). Simple first flush diverters require active management by draining the first flush water volume to a pervious area following each rainstorm. First flush diverters may be the preferred pre-treatment method if the water is to be used for indoor purposes. A vortex filter may serve as an effective pre-tank filtration device and first flush diverter.

  - **Leaf Screens.** Leaf screens are mesh screens installed over either the gutter or downspout to separate leaves and other large debris from rooftop runoff. Leaf screens shall be regularly cleaned to be effective; if not maintained, they can become clogged and prevent rainwater from flowing into the storage tanks. Built-up debris can also harbor bacterial growth within gutters or downspouts (TWDB, 2005).

  - **Roof Washers.** Roof washers are placed just ahead of storage tanks and are used to filter small debris from harvested rainwater (**Figure 6.13.11**). Roof washers consist of a tank, usually between 25 and 50 gallons in size, with leaf strainers and a filter with openings as small as 30-microns (TWDB, 2005). The filter functions to remove very small particulate matter from harvested rainwater. All roof washers shall be cleaned on a regular basis.

Figure 6.13.10. First Flush Diverter
(Source: VADCR, 2011)

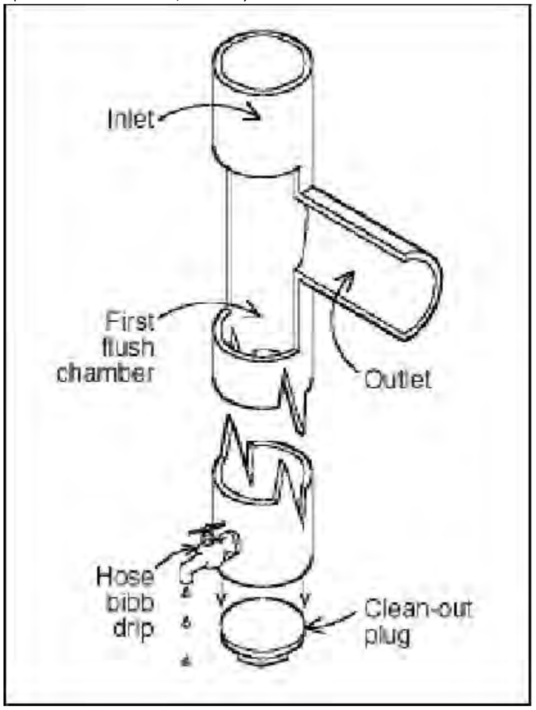
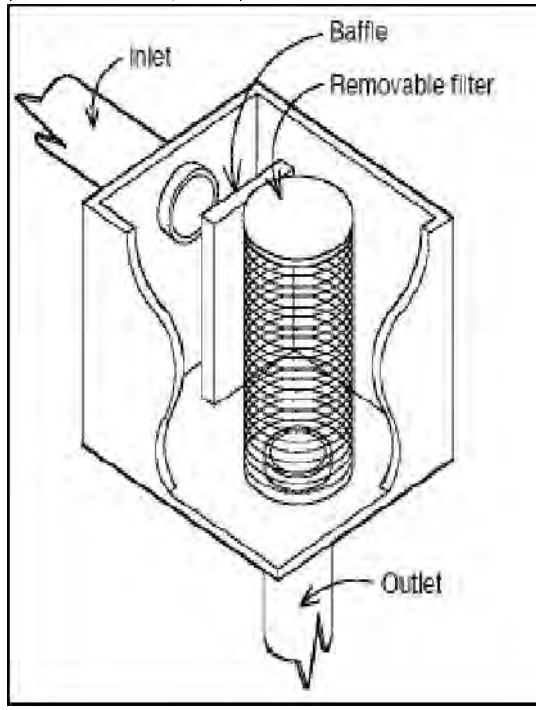


Figure 6.13.11. Roof Washer
(Source: VADCR, 2011)



- **Vortex Filters.** For large scale applications, vortex filters can provide filtering of rooftop rainwater from larger rooftop areas. **Figure 6.13.12** provides a plan view photograph showing the interior of the filter with the top off and the filter just installed in the field prior to the backfill.

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Figure 6.13.12. Interior of Vortex (top) and Installation of Vortex Filter Prior to Backfill (bottom) *(Source: VADCR, 2011)*

Storage Tanks. The storage tank is the most important and typically the most expensive component of a rainwater harvesting system. Cistern capacities range from 250 to over 30,000 gallons. Multiple tanks can be placed adjacent to each other and connected with pipes to balance water levels and increase overall storage on-site as needed. Typical rainwater harvesting system capacities for residential use range from 1,500 to 5,000 gallons. Storage tank volumes are calculated to meet the water demand and storm water treatment volume objectives, as described above.

While many of the graphics and photos in this specification depict cisterns with a cylindrical shape, the tanks can be made of many materials and configured in various shapes, depending on the type used and the site conditions where the tanks will be installed. For example, configurations can be rectangular, L-shaped, or step vertically to match the topography of a site. The following factors shall be considered when designing a rainwater harvesting system and selecting a storage tank:

- Aboveground storage tanks shall be UV and impact resistant.
- Underground storage tanks shall be designed to support the overlying sediment and any other anticipated loads (e.g., vehicles, pedestrian traffic, etc.).
- Underground rainwater harvesting systems shall have a standard size manhole or equivalent opening to allow access for cleaning, inspection, and maintenance purposes. This access point shall be secured/locked to prevent unwanted access.
- All rainwater harvesting systems shall be sealed using a water-safe, non-toxic substance.
- Rainwater harvesting systems may be ordered from a manufacturer or can be constructed on site from a variety of materials. **Table 6.13.2** below compares the advantages and disadvantages of different storage tank materials.
- Storage tanks shall be opaque or otherwise protected from direct sunlight to inhibit algae growth and shall be screened to discourage mosquito breeding and reproduction.
- Dead storage below the outlet to the distribution system and an air gap at the top of the tank shall be added to the total volume. For gravity-fed systems, a minimum of 6 inches of dead storage shall be provided. For systems using a pump, the dead storage depth will be based on the pump specifications.
- Any hookup to a municipal backup water supply shall have a backflow prevention device to keep municipal water separate from stored rainwater. Check with the City Water Department for any regulations pertaining to this.

Table 6.13.2. Advantages and Disadvantages of Various Cistern Materials

Tank Material	Advantages	Disadvantages
Fiberglass	Commercially available, alterable, and moveable; durable with little maintenance; light weight; integral fittings (no leaks); broad application	Shall be installed on smooth, solid, level footing; pressure proof for below-ground installation; expensive in smaller sizes
Polyethylene	Commercially available, alterable, moveable, affordable; available in wide range of sizes; can install above or below ground; little maintenance; broad application	Can be UV-degradable; shall be painted or tinted for above-ground installations; pressure-proof for below-ground installation
Modular Storage	Can modify to topography; can alter footprint and create various shapes to fit site; relatively inexpensive	Longevity may be less than other materials; higher risk of puncturing of water tight membrane during construction
Plastic Barrels	Commercially available; inexpensive	Low storage capacity (20 to 50 gallons); limited application
Galvanized Steel	Commercially available, alterable, and moveable; available in a range of sizes; film develops inside to prevent corrosion	Possible external corrosion and rust; shall be lined for potable use; can only install above ground; soil pH may limit underground applications
Steel Drums	Commercially available, alterable, and moveable	Small storage capacity; prone to corrosion, and rust can lead to leaching of metals; verify prior to reuse for toxics; water pH and soil pH may also limit applications

Tank Material	Advantages	Disadvantages
FerroConcrete	Durable and immoveable; suitable for above or below ground installations; neutralizes acid rain	Potential to crack and leak; expensive
Cast in Place Concrete	Durable, immoveable, versatile; suitable for above or below ground installations; neutralizes acid rain	Potential to crack and leak; permanent; will need to provide adequate platform and design for placement in clay soils
Stone or Concrete Block	Durable and immoveable; keeps water cool in summer months	Difficult to maintain; expensive to build

Source: Cabell Brand (2007, 2009)

6.13.3 Design Requirements

Cistern design does not have a design table. Runoff reduction credits are based on the total amount of annual internal water reuse, outdoor water reuse, and tank dewatering discharge calculated to be achieved by the tank system. Volume reduction for cisterns is detailed in **Table 6.13.3**.

Table 6.13.3. Annual Runoff Volume Reduction Provided by Rainwater Harvesting

Storm Water Function	Performance
Annual Runoff Volume Reduction (RR)	Variable up to 90% [1]

1 Credit is variable. Credit up to 90% is possible if all water from storms with rainfall of 1 inch or less is used through demand, and the tank is sized such that no overflow from this size event occurs. The total credit may not exceed 90%.

Sizing of Urban Bioretention Practices

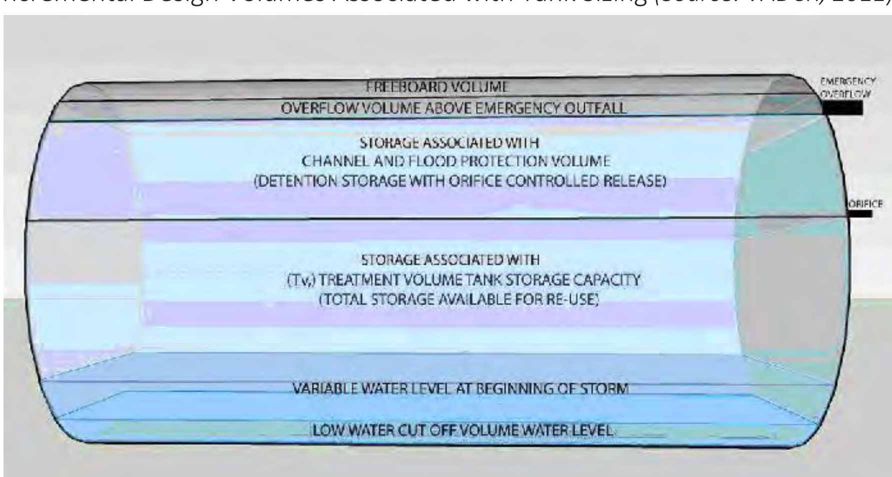
Storm Water Quality

The rainwater harvesting cistern sizing criteria presented in this section was developed using best estimates of indoor and outdoor water demand, long-term rainfall data, and rooftop capture area data.

Incremental Design Volumes within Cistern

Rainwater tank sizing is determined by accounting for varying precipitation levels, captured rooftop runoff, first flush diversion (through filters) and filter efficiency, low water cut-off volume, dynamic water levels at the beginning of various storms, storage needed for treatment volume (permanent storage), storage needed for channel protection and flood volume (temporary detention storage), seasonal and year-round demand use and objectives, overflow volume, and freeboard volumes above high water levels during very large storms. See **Figure 6.13.13** for a graphical representation of these various incremental design volumes.

Figure 6.13.13. Incremental Design Volumes Associated with Tank Sizing *(Source: VADCR, 2011)*



The "Storage Associated with the Treatment Volume" is the storage within the tank that is modeled and available for reuse. While the Treatment Volume will remain the same for a specific rooftop capture area, the "Storage Associated with the Treatment Volume" may vary depending on demand and runoff reduction credit objectives. It includes the variable water level at the beginning of a storm and the low water cut-off volume that is necessary to satisfy pumping requirements.

Rainwater Harvesting Material Specifications

The basic material specifications for rainwater harvesting systems are presented in **Table 6.13.4**. Designers shall consult with experienced rainwater harvesting system and irrigation installers on the choice of recommended manufacturers of prefabricated tanks and other system components.

Table 6.13.4. Design Specifications for Cisterns

Item	Specification
Gutters and Downspout	Materials commonly used for gutters and downspouts include PVC pipe, vinyl, aluminum, and galvanized steel. Lead shall not be used as gutter and downspout solder since rainwater can dissolve the lead and contaminate the water supply. - The length of gutters and downspouts is determined by the size and layout of the catchment and the location of the storage tanks. - Be sure to include needed bends and tees.
Pre-Treatment	At least one of the following (all rainwater to pass through pre-treatment): - First flush diverter - Vortex filter - Roof washer - Leaf and mosquito screen (1 mm mesh size)
Storage Tanks	- Materials used to construct storage tanks shall be structurally sound. - Tanks shall be constructed in areas of the site where native soils can support the load associated with stored water. - Storage tanks shall be water tight and sealed using a water-safe, non-toxic substance. - Tanks shall be opaque to prevent the growth of algae. - Re-used tanks shall be fit for potable water or food-grade products. - Underground rainwater harvesting systems shall have a minimum of 18 to 24 inches of soil cover and be located below the frost line. - The size of the rainwater harvesting system(s) is determined during the design calculations.

Note: This table does not address indoor systems or pumps.

6.13.4 Construction, Protection, and Maintenance Requirements

All GIPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all GIPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For City policies, additional guidance, and forms pertaining to GIP protection, inspection, and maintenance requirements, see Appendix B of this manual.

Requirements During Construction

- Appropriate containment shall be used for material storage to prevent accidental discharge to the cistern.
- A dense and vigorous vegetative cover, or other effective soil stabilization practice, shall be established over area receiving overflow runoff before storm water can be accepted into the cistern. This will prevent erosion down-gradient of the cistern.

Protection Requirements

- Provide signage for the GIP.
  - Allows for easy identification and location of the GIP.
  - Serves as a general education tool, making those responsible for property, landscape or GIP maintenance, and the general public aware of the water quality features of the GIP and to avoid encroachment.
- Design the layout of the urban bioretention area such that maintenance access can be achieved without the need for vehicles or equipment in the storm water treatment area.
- Provide clearly marked, easily accessible, and well-maintained driveways, sidewalks, and pedestrian pathways that lead vehicles, equipment, and foot traffic around the storm water treatment areas.

Inspection Requirements

- Inspect for damaged cistern and rooftop components.
- Inspect the property that receives water and overflow for signs of erosion.

Maintenance Requirements

- Inspect surrounding area for sediment build up, erosion, vegetative health/conditions, etc. Perform appropriate maintenance as necessary.
- Inspect cistern for signs of corrosion or failure and maintain as needed.

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6.14 Dry Detention Pond/Dry Extended Detention Pond

Figure 6.14.1. Example of Dry Detention Pond

DEVELOPMENT ATTRIBUTES

Construction Cost	LOW
Operation and Maintenance Cost	MODERATE
Ground-Level Encroachment	HIGH
Building Footprint Enhancement	HIGH
Triple Bottom-Line Benefits	MODERATE

Description:

A surface storage basin or facility designed to provide water quality treatment and water quantity control through extended detention (ED) of storm water. Dry ED basins differ from dry detention basins in that they provide 24-hour detention of the channel protection volume (CP_v).

Variations:

- Dry extended detention (ED)
- Multiple pond system

Key Advantages:

- Moderate removal rate of urban pollutants
- High community acceptance
- Useful for water quality treatment, channel protection, and flood control
- Dry ED basins can serve multiple purposes on a development site
- Settling pools within the dry ED basin mitigate potential thermal impacts

Key Limitations:

- Dam height restrictions for high relief areas
- Drainage from the ED basin can be problematic for low relief terrain

PERFORMANCE STANDARD COMPLIANCE						
Water Quality			Stream Channel Protection	Overbank Flood Protection	Extreme Flood Protection
Treatment Volume		80% TSS Removal			
Level 1	Level 2				
Not Approved	Not Approved	▶	▶	▶	▶

✓ Suitable for this practice

▶ Provides partial benefits

6.14.1 General Application

Figure 6.14.2. Example of Dry Detention Pond

Dry ED basins are surface facilities intended to provide for the temporary storage and treatment of storm water runoff to reduce downstream water quality and water quantity impacts. These facilities temporarily detain storm water runoff, releasing the flow over a period of time. They are designed to completely drain within 24 to 72 hours after a storm event and are normally dry between rain events.

Dry ED basins provide downstream channel protection through extended detention of the channel protection volume (CP_v). Dry ED basins are intended to provide overbank flood protection (peak flow reduction of the 25-year, 24-hour storm, Q_{p25}) and can be designed to control the extreme flood (100-year, 24-hour, Q_f) storm event.

While dry ED ponds can provide for flood protection, they will rarely provide adequate runoff volume reduction and pollutant removal to serve as a stand-alone compliance strategy. Therefore, designers shall always maximize the use of upland runoff reduction practices (e.g., rooftop disconnections, small-scale infiltration, rainwater harvesting, bioretention, grass channels and water quality swales) that reduce runoff at its source (rather than merely treating the runoff at the terminus of the storm drain system). Upland runoff reduction practices can be used to satisfy most or all the runoff reduction requirements at most sites. Upland runoff reduction practices will greatly reduce the size, footprint, and cost of the downstream dry ED pond.

When locating a dry detention basin, the site designers shall also consider the location and use of other land use features, such as planned open spaces and recreational areas, and should attempt to achieve a multi-use objective with the basin where this can be safely achieved. A typical schematic for a dry ED basin is shown in **Figure 6.14.3**.

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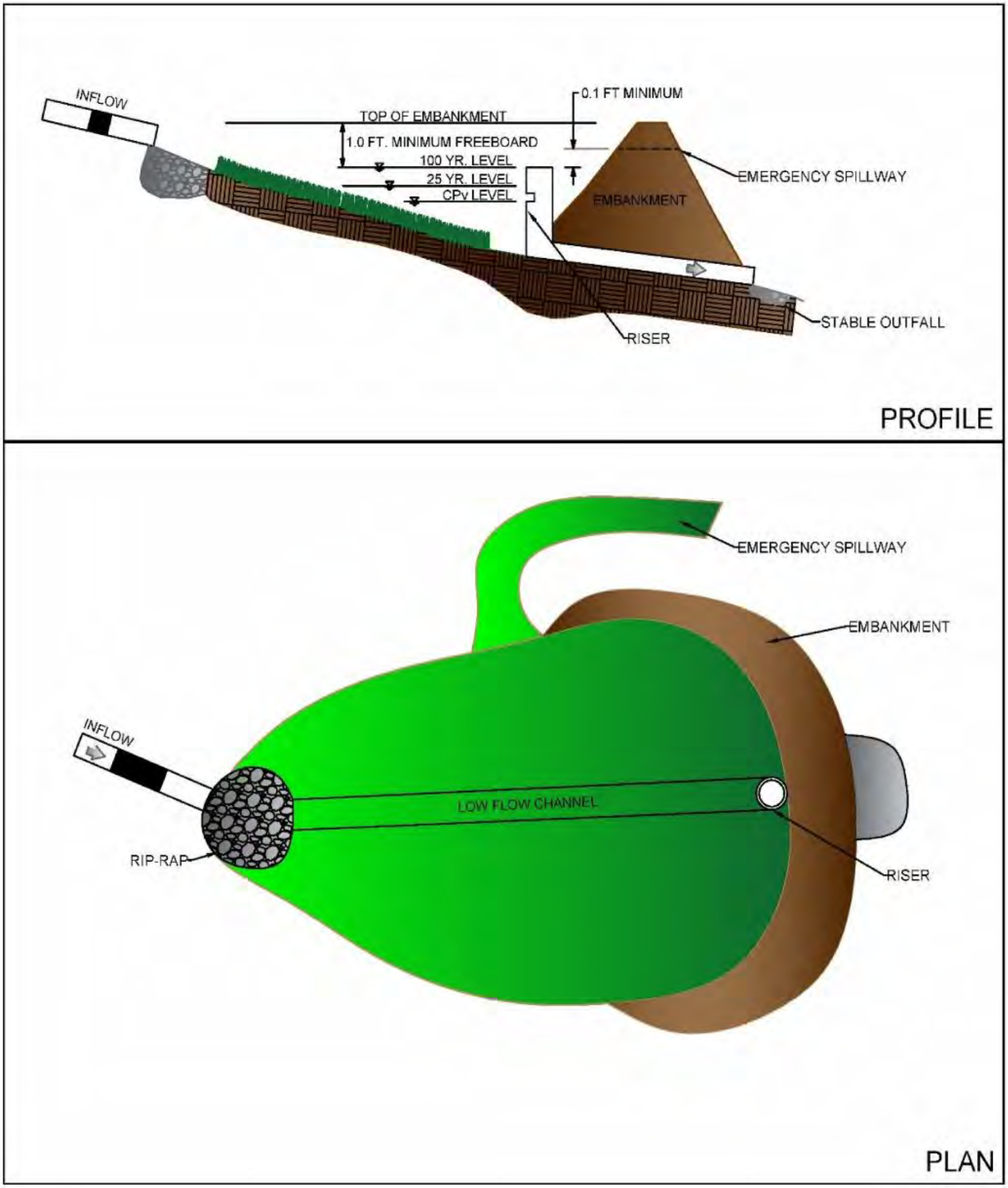
Figure 6.14.3 Schematic of Dry Extended Detention Pond



6.14.2 Planning and Physical Feasibility

The following feasibility issues need to be evaluated when dry ED ponds are considered as the final practice in a treatment train. Many of these issues will be influenced by the type of dry ED Pond being considered. The following criteria provided it **Table 6.14.1** shall be considered when evaluating the suitability of a dry ED pond for a development site.

Table 6.14.1. Dry ED Pond Constraints

Contributing Drainage Area	Embankment Slopes	Hotspot Land Uses	Hydraulic Head Needed	Karst Areas	Setbacks
10 acre min. unless water balance calculations support pocket ponds.	<20 feet in height and side slopes no steeper than 2:1 (horizontal to vertical), although 3:1 is preferred.	Significant separator from groundwater and/or liner required.	6-10’ min.	See Technical bulletin No. 1 (CSN, 2009) for guidance. Impermeable clay or (preferably) geosynthetic liner required.	Property lines require 10 feet. Building foundations require 10 feet. Septic systems require 50 feet. Private wells require 100 feet. Open water requires 100 feet. Public water supply reservoir requires 200 feet. Public water supply wells require 1,200 feet.
Site Slope	**Soils Requirement**	**Space Required**	**Trout Stream**	**Water Table Requirement**	
≤15%	Infiltration and geotechnical tests required. Infiltration encouraged unless embankment integrity is affected.	2-3% of the contributing drainage area	Not effective for protecting trout streams due to potential for thermal impacts, suspended solids, or soluble pollutants.	The basin shall not intersect the water table.	

The data listed below is necessary for the design of a dry ED pond and shall be included with the development plan. See Appendix B for more information on required elements for the development plan.

- Existing and proposed site, topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Water surface elevation of nearby water systems as well as the depth to seasonally high groundwater.
- Infiltration testing of native soils at proposed elevation of bottom of dry ED pond.

6.14.3 Design Requirements

The designer shall calculate CP_v, Q_{p25}, and Q_f in accordance with the guidance presented in Chapter 4.

Then the designer shall determine pretreatment volume. A sediment forebay is provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the basin. The forebay shall be sized to contain 0.1 inch per impervious acre of contributing drainage.

Then the designer shall design the emergency overflow system. Calculate the 100-year water surface elevation, set the top of the embankment elevation, and analyze safe passage of the Q_f. Set the invert elevation of the emergency spillway 0.1 foot above the 100-year water surface elevation.

Then the designer shall set up a stage-storage-discharge relationship for the control structure for the 25- and 100-year, 24-hour storm orifices to design embankment(s) and spillway(s).

Sizing of Dry ED Pond Practices

Storm Water Quality

Designers can use a site-adjusted R_v (see Chapter 4), which reflects the use of upland runoff reduction practices, to compute the remaining treatment and flood protection volumes that shall be treated by the ED dry pond. ED dry ponds shall then be designed to capture and treat the remaining runoff volume as necessary, using methodology found below and in Chapter 4. The water quality treatment approach shall be calculated by Equation 1.

Equation 1. Water Quality Volume

$$WQ_V = (1.2)\,(RV)\,(A)\,/\,12$$

Where:

WQ_V = Water Quality Volume (cubic feet)

1.2 = Target rainfall amount to be treated (inches)

RV = Volumetric runoff coefficient which can be found by:

$RV = 0.05 + 0.009(I)$

Where:

I = new impervious area of the contributing drainage area (%)

A = Area draining to this practice (square feet)

12 = Unit conversion factor (in/ft.)

Once the low flow orifice has been sized, design embankments and emergency spillways, investigate potential dam hazard classifications, and finally design inlets, sediment forebays, outlet structures, maintenance access, and safety features. These items are detailed below.

Required Geotechnical Testing

Soil borings shall be taken below the proposed embankment, near the proposed outlet area and in at least two locations within the proposed dry ED pond treatment area. Soil boring data is needed to (1) determine the physical characteristics of the excavated material, (2) determine its adequacy for use as structural fill or spoil, (3) provide data for structural designs of the outlet works (e.g., bearing capacity and buoyancy), (4) determine compaction/composition needs for the embankment, (5) determine the depth to groundwater and bedrock, and (6) evaluate potential infiltration losses (and the potential need for a liner).

Pre-Treatment Forebay

Sediment forebays are an integral design feature to maintain the longevity of dry ED ponds. A forebay shall be located at each major inlet to trap sediment and preserve the capacity of the main treatment cell. Other forms of pre-treatment for sheet flow and concentrated flow for minor inflow points shall be designed consistent with pre-treatment criteria found in Chapter 6, Section 3. The following criteria apply to forebay design:

- Inflow channels are to be stabilized with flared aprons, or the equivalent.
- Pretreatment for a dry ED basin is usually provided by a sediment forebay. The sediment forebay shall be sized to 0.1 inches of runoff per impervious acre of contributing drainage area for dry ED basins.
- Pretreatment may also be provided by using a grass filter strip, pea gravel diaphragm, or grass channel. Where filter strips are used, 100% of the contributing runoff shall flow across the filter strip. Refer to Chapter 6, Section 8.

Outlets
The outlet structures shall meet the following specifications:

- For a dry ED basin, the outlet structure is sized for Q_{p25} control (based upon hydrologic routing calculations) and can consist of a weir, orifice, outlet pipe, combination outlet, or other acceptable control structure. Small outlets that will be prone to clogging or difficult to maintain are not acceptable.
- A dry ED basin has a channel protection orifice with a minimum diameter of 3 inches and shall be adequately protected from clogging by an acceptable external trash rack. The orifice diameter may be reduced to 1 inch if internal orifice protection is used (e.g., an over perforated vertical stand pipe with 0.5-inch orifices or slots that are protected by wire cloth and a stone filtering jacket). Adjustable gate valves can also be used to achieve this equivalent diameter.
- Seepage control or anti-seep collars shall be provided for all outlet pipes.
- Riprap, plunge pools or pads, or other energy dissipaters are to be placed at the end of the outlet to prevent scouring and erosion. If the basin discharges to a channel with dry weather flow, care shall be taken to minimize tree clearing along the downstream channel and to reestablish a forested riparian zone in the shortest possible distance from the dry ED basin.

Internal Design Features
Design shall include the following:

- Vegetated embankments shall be less than 20 feet in height and shall have side slopes no steeper than 2:1 (horizontal to vertical) although 3:1 is preferred.
- Riprap-protected embankments shall be no steeper than 2:1. Geotechnical slope stability analysis is recommended for embankments greater than 10 feet in height and is mandatory for embankment slopes steeper than those given above.
- The depth of the basin shall not exceed 10 feet.
- Areas above the normal high water elevations of the detention facility shall be sloped toward the basin to allow drainage. Careful finish grading is required to avoid creation of upland surface depressions that may retain runoff. The bottom area of storage facilities shall be graded toward the outlet to prevent standing water conditions.
- Designing dry ED basins with a high length to width ratio (i.e., at least 1.5:1) and incorporating other design features to maximize the flow path effectively increases detention time by eliminating the potential of flow to short circuit the basin. Designing basins with relatively flat side slopes can also help to lengthen the effective flow path.
- While there is no minimum slope requirement, enough elevation drop is needed from the basin inlet to the basin outlet to ensure that flow can move through the system.
- A low flow or pilot channel across the facility bottom from the inlet to the outlet is recommended to convey low flows and prevent standing water conditions. To prevent stream warming, designers shall place landscaping to provide shade around the pilot channel and the basin outlet. Designing the pilot channel as a grass channel also reduces thermal impacts. A minimum slope of 1% is required for grass swales and 0.5% for armored pilot channels.

Safety features shall include the following:

- An emergency spillway shall be included in the dry ED basin design to safely pass the extreme flood flow.

The spillway prevents basin water levels from overtopping the embankment and causing structural damage. The emergency spillway shall be designed so that downstream structures will not be impacted by spillway discharges.

- A minimum of 1 foot of freeboard shall be provided, measured from the top of the water surface elevation for the extreme flood to the lowest point of the dam embankment, not counting the emergency spillway. A safety bench shall be provided for embankments greater than 10 feet in height and having a side slope steeper than 3:1. For large basins, the safety bench shall extend no less than 15 feet outward from the normal water edge to the toe of the basin side slope. The slope of the safety bench shall not exceed 6%.
- Storm water shall be conveyed to and from dry ED basins safely and to minimize erosion potential.

Landscaping and Planting Plan

A landscaping plan shall be provided that indicates the methods used to establish and maintain vegetative coverage within the dry ED pond. For more guidance refer to Appendix C. Minimum elements of a plan include the following:

- Designers shall maintain a vegetated buffer around the dry ED basin and select plants within the detention zone (i.e., the portion of the basin up to the elevation where storm water is detained) that can withstand both wet and dry periods. The side slopes of dry basins shall be relatively flat to reduce safety risks.
- Selection of corresponding plant species
- The planting plan
- Sources of plant material
- The planting plan shall allow the pond to mature into a native forest in the right places yet keep mowable turf along the embankment and all access areas.
- Woody vegetation may not be planted or allowed to grow within 15 feet of the toe of the embankment nor within 25 feet from the principal spillway structure.
- Avoid species that require full shade or are prone to wind damage. Extra mulching around the base of trees and shrubs is strongly recommended as a means of conserving moisture and suppressing weeds.
- Bare soil is not permitted in the ED area. Non-vegetated areas shall be stabilized using mulch or other appropriate ground cover.
- Trees planted on or near the side slopes of the dry ED basin can intercept and slow rainfall, reducing its erosive force before hitting the ground. The trees also transpire soil moisture within the basin. There is an added benefit of rainfall storage that is held within the tree canopy and does not reach the ground.

Maintenance Reduction Features

Good maintenance access is needed so crews can remove sediments from the forebay, alleviate clogging, and make riser repairs. The following dry ED pond maintenance issues can be addressed during design to make ongoing maintenance easier:

- Adequate maintenance access shall extend to the forebay and outlet structure and shall have sufficient area to allow vehicles to turn around.
- The riser shall be located within the embankment for maintenance access, safety, and aesthetics.
- Access roads shall (1) be constructed of load-bearing materials or be built to withstand the expected

frequency of use, (2) have a minimum width of 12 feet, and (3) have a profile grade that does not exceed 15%. Steeper grades are allowable if appropriate stabilization techniques are used, such as a gravel road.

- A maintenance right-of-way or easement shall extend to the dry ED pond from a public or private road.

ED Dry Pond Material Specifications

Dry ED ponds are generally constructed with materials obtained on-site except for the plant materials, inflow and outflow devices (e.g., piping and riser materials), possibly stone for inlet and outlet stabilization, and filter fabric for lining banks or berms.

Emergency spillways shall be sized for any overtopping of pond in case of rain event in excess of 100-year storm and for instances of malfunction or clogging of primary outlet structure.

6.14.4 Construction, Protection, and Maintenance Requirements

All GIPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all GIPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For City policies, additional guidance, and forms pertaining to GIP protection, inspection, and maintenance requirements, see Appendix B of this manual.

Requirements During Construction

- A dense and vigorous vegetative cover, or other effective soil stabilization practice, shall be established over the contributing pervious drainage areas before storm water can be accepted into the dry ED pond. This will prevent sediment from accumulating in the basin.

Protection Requirements

- Provide signage for the GIP.
    - Allows for easy identification and location of the GIP.
    - Serves as a general education tool, making those responsible for property, landscape or GIP maintenance, and the general public aware of the water quality features of the GIP and to avoid encroachment.
- Design the layout of the dry ED pond such that maintenance access can be achieved without the need for vehicles or equipment in the storm water treatment area.

Inspection Requirements

- Inspect the areas where storm water flows into or out of the dry ED pond for clogging or sediment buildup.
- Inspect trees, shrubs, and other vegetation to ensure they meet landscaping and vegetation specifications. Replace if necessary.
- Inspect the property that drains to the dry ED pond for erosion, exposed soil or stockpiles of other potential pollutants.

Maintenance Requirements

- Perform weeding, pruning, and trash removal as needed to maintain appearance.
- Inspect vegetation to evaluate health, replace if necessary.
- Keep inlets clear of debris to prevent clogging, clear if necessary.
- Inspect dry ED pond area for sediment build up, erosion, vegetative health/conditions, etc. perform appropriate maintenance as necessary.

6.15 Extended Detention Pond/Storm Water Wet Pond

80% TSS Removal

Storage Reuse

Figure 6.15.1. Star Lake in Birmingham, AL

DEVELOPMENT ATTRIBUTES

Construction Cost	LOW
Operation and Maintenance Cost	MODERATE
Ground-Level Encroachment	HIGH
Building Footprint Enhancement	HIGH
Triple Bottom-Line Benefits	MODERATE

Description:

Constructed storm water detention basin that has a permanent pool (or micropool). Runoff from each rain event is captured and treated primarily through settling and biological uptake mechanisms.

Variations:

- Wet extended detention (ED)
- Micropool ED
- Multiple pond system

Key Advantages:

- Can be designed as a multi-functional GIP
- Cost effective
- Can be designed as an amenity within a development
- Wildlife habitat potential
- High community acceptance when integrated into a development

Key Limitations:

- Potential for thermal impacts downstream
- Not recommended in karst terrain
- Community perceived concerns with mosquitoes and safety

PERFORMANCE STANDARD COMPLIANCE					
Water Quality			Stream Channel Protection	Overbank Flood Protection	Extreme Flood Protection
Treatment Volume		80% TSS Removal			
Level 1	Level 2				
7 RR Credit	Not Approved	✓	▶	▶	▶

✓ Suitable for this practice

▶ Provides partial benefits

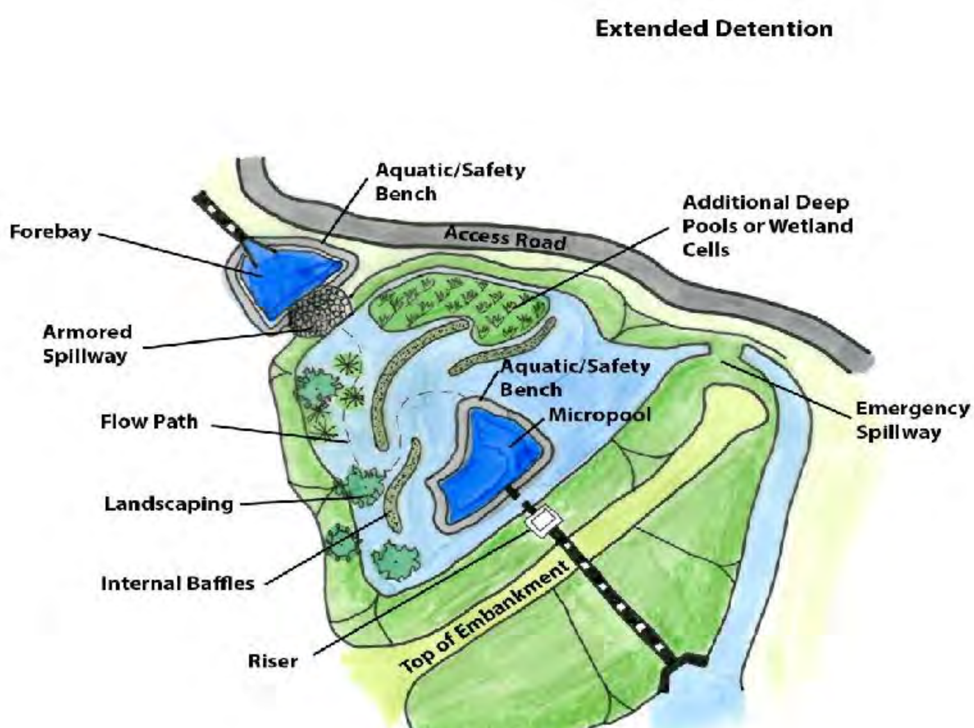
6.15.1 General Application

Figure 6.15.2. Rain Curtain, Railroad Park, Birmingham, AL

An Extended Detention (ED) Pond relies on a 24- to 48-hour detention of storm water runoff after each rain event. An under-sized outlet structure restricts storm water flow, so it backs up and is stored within the basin. The temporary ponding enables particulate pollutants to settle out and reduces the maximum peak discharge to the downstream channel, thereby reducing the effective shear stress on banks of the receiving stream. ED differs from storm water detention, since it is designed to achieve a minimum drawdown time, rather than a maximum peak rate of flow (which is commonly used to design for peak discharge or flood control purposes and often detains flows for just a few minutes or hours). ED ponds rely on gravitational settling as their primary pollutant removal mechanism. Consequently, they generally provide fair-to-good removal for particulate pollutants, but low or negligible removal for soluble pollutants, such as nitrate and soluble phosphorus. The use of ED alone generally results in a low overall pollutant removal. As a result, ED is normally combined with other practices to maximize pollutant removal rates.

While ED ponds can provide for flood protection, they will rarely provide adequate runoff volume reduction and pollutant removal to serve as a stand-alone compliance strategy. Therefore, designers should always maximize the use of upland runoff reduction practices (e.g., rooftop disconnections, small-scale infiltration, rainwater harvesting, bioretention, grass channels and water quality swales) that reduce runoff at its source (rather than merely treating the runoff at the terminus of the storm drain system). Upland runoff reduction practices can be used to satisfy most or all of the runoff reduction requirements at most sites. Upland runoff reduction practices will greatly reduce the size, footprint, and cost of the downstream ED pond.

When locating a dry detention basin, the site designers should also consider the location and use of other land use features, such as planned open spaces and recreational areas, and should attempt to achieve a multi-use objective with the basin where this can be safely achieved.



6.15.2 Planning and Physical Feasibility

The following feasibility issues need to be evaluated when ED ponds are considered as the final practice in a treatment train. Many of these issues will be influenced by the type of ED Pond being considered. The following criteria provided in **Table 6.15.1** shall be considered when evaluating the suitability of an ED pond for a development site.

Table 6.15.1. ED Pond Constraints

Contributing Drainage Area	Hydraulic Head Needed	Karst Areas
10 acres min. unless water balance calculations support pocket ponds	6-10' min.	See Technical bulletin No. 1 (CSN, 2009) for guidance. Impermeable clay or (preferably) geosynthetic liner required.
Setbacks	Soils Requirement	Water Table Requirement
Property lines require 10'. Building foundations require 25 feet. Septic systems require 50'. Private wells require 100 feet.	Infiltration and geotechnical tests required. Infiltration encouraged unless embankment integrity is affected.	Less than 3 feet of vertical separation above the underlying soil-bedrock interface requires a liner.

The data listed below is necessary for the design of an ED pond and shall be included with the development plan. See Appendix B for more information on required elements for the development plan.

- Existing and proposed site, topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Water surface elevation of nearby water systems as well as the depth to seasonally high groundwater.
- Infiltration testing of native soils at proposed elevation of bottom of ED pond.

6.15.3 Design Requirements

ED ponds shall be designed with a Storage Volume, T_V. **Table 6.15.2** lists the criteria for qualifying designs. Level 2 design is not approved for RR.

Table 6.15.2. Extended Detention (ED) Pond Design Criteria

Level 1 Design Only (RR: 7)
Tv^1 = [(1.25) (Rv) (A)] *3630 – the volume reduced by an upstream GIP
A minimum of 40% of Tv in the permanent pool (forebay, micropool, deep pool, or wetlands)
Length/Width ratio *OR* flow path = 3:1 or more
Length of the shortest flow path / overall length = 0.7 or more
Minimum T_v ED time = 24 hours
Maximum vertical T_v ED limit of 4 feet
Trees and wetlands in the planting plan
Includes additional cells or features (deep pools, wetlands, etc.). See below.
CDA is greater than 10 acres unless water balance supports smaller contributing drainage area (CDA)

1 A= Area in Acres

Sizing of ED Pond Practices

Storm Water Quality

Designers can use a site-adjusted R_v (see Chapter 4), which reflects the use of upland runoff reduction practices, to compute the remaining treatment and flood protection volumes that shall be treated by the ED pond. ED ponds shall then be designed to capture and treat the remaining runoff volume as necessary, using methodology found below and in Chapter 4. Runoff treatment (T_v) credit may be taken for the entire water volume below the permanent pool elevation of any micropools, forebays, and wetland areas, as well as, the temporary extended detention above the normal pool. A minimum of 40% of the T_v shall be designed into the permanent pool.

Equation 1. ED Treatment Volume

$$T_v \text{ (cu. ft.)} = (\text{Original } T_v - \text{the volume reduced by an upstream GIP})$$

After calculating T_V, the forebay shall be sized using guidance in Chapter 6, Section 2. The outlets shall then be sized for appropriate storm events. If the pond is additionally going to address peak flow attenuation, the downstream impacts shall be considered for the 2- through 100-year events. Refer to Chapter 6, Section 2 for instruction on design of outlet orifices and weirs.

Low flow orifices can be sized using the following equation. For more information on the design of outlet orifices and weirs and for achieving the target drawdown of the Treatment Volume design, refer to Chapter 6, Section 2. If a different equation is used or different type of low flow orifice is used, provide supporting calculations.

Equation 2. Area of Low Flow Orifice

$$a = \frac{2A(H - H_o)^{0.5}}{3600CT(2g)^{0.5}}$$

Where:

- a = Area of orifice (ft^2)
- A = Average surface area of the pond (ft^2)
- C = Orifice coefficient, 0.66 for thin, 0.80 for materials thicker than orifice diameter
- T = Drawdown time of pond (hrs), shall be greater than 24 hours
- g = Gravity (32.2 ft/sec^2)
- H = Elevation when pond is full to storage height (ft)
- Ho = Final elevation when pond is empty (ft)

Table 6.15.2 provides maximum ponding depths and other criteria for providing runoff volume reduction. Once the low flow orifice has been sized, design embankments and emergency spillways, investigate potential dam hazard classifications, and finally design inlets, sediment forebays, outlet structures, maintenance access, and safety features. These items are detailed below.

Required Geotechnical Testing

Soil borings shall be taken below the proposed embankment, in the vicinity of the proposed outlet area, and in at least two locations within the proposed ED pond treatment area. Soil boring data is needed to (1) determine the physical characteristics of the excavated material, (2) determine its adequacy for use as structural fill or spoil, (3) provide data for structural designs of the outlet works (e.g., bearing capacity and buoyancy), (4) determine compaction/composition needs for the embankment, (5) determine the depth to groundwater and bedrock, and (6) evaluate potential infiltration losses (and the potential need for a liner).

Pre-Treatment Forebay

Sediment forebays are considered to be an integral design feature to maintain the longevity of ED ponds. A forebay shall be located at each major inlet to trap sediment and preserve the capacity of the main treatment cell. Other forms of pre-treatment for sheet flow and concentrated flow for minor inflow points shall be designed consistent with pre-treatment criteria found in Chapter 6, Section 3: Bioretention. The following criteria apply to forebay design:

- A major inlet is defined as an individual storm drain inlet pipe or open channel serving at least 10% of the ED pond's contributing drainage area.
- The forebay consists of a separate cell, formed by an acceptable barrier. (e.g., an earthen berm, concrete weir, gabion baskets, etc.).
- The forebay shall be at least 4 feet deep and shall be equipped with a variable width aquatic bench for safety purposes. The aquatic benches shall be 4 to 6 feet wide at a depth of 18 inches below the water surface.
- The total volume of all forebays shall be at least 15% of the total Treatment Volume. The relative size of individual forebays shall be proportional to the percentage of the total inflow to the pond. Similarly, any outlet protection associated with the end section or end wall shall be designed according to state or local design standards.
- The forebay shall be designed in such a manner that it acts as a level spreader to distribute runoff evenly across the entire bottom surface area of the main treatment cell.
- The bottom of the forebay may be hardened (e.g., concrete, asphalt, or grouted riprap) to make sediment removal easier.

Conveyance and Overflow

Micropool ED ponds shall not have a low flow pilot channel, but instead shall be constructed in a manner whereby flows are evenly distributed across the pond bottom, to promote the maximum infiltration possible.

Internal Slope: The maximum longitudinal slope through the pond shall be approximately 0.5% to 1% to promote positive flow through the ED pond.

The primary spillway shall be designed with acceptable anti-flotation, anti-vortex, and trash rack devices. The spillway shall generally be accessible from dry land.

ED Ponds with drainage areas of 10 acres or less, where small diameter pipes are typical, are prone to chronic clogging by organic debris and sediment. Orifices less than 3 inches in diameter may require extra attention during design to minimize the potential for clogging. Designers shall always look at upstream conditions to assess the potential for higher sediment and woody debris loads. The risk of clogging in outlet pipes with small orifices can be reduced by:

- Providing a micropool at the outlet structure:
    - Use a reverse-sloped pipe that extends to a mid-depth of the permanent pool or micropool.
    - Install a downturned elbow or half-round corrugated metal pipe (CMP) over a riser orifice (circular, rectangular, V-notch, etc.) to pull water from below the micropool surface.
    - The depth of the micropool shall be at least 4 feet deep, and the depth may not draw down by more than 2 feet during 30 consecutive days of dry weather in the summer.
- Providing an over-sized forebay to trap sediment, trash, and debris before it reaches the ED pond's low-flow orifice.
- Installing a trash rack to screen the low-flow orifice.

- ❖ Using a perforated pipe under a gravel blanket with an orifice control at the end in the riser structure to supplement the primary outlet.

Emergency Spillways, Inlets, and Outlets

ED ponds shall be constructed with overflow capacity to pass the 100-year design storm event through either the Primary Spillway or a vegetated or armored Emergency Spillway.

The design shall specify an outfall that will be stable for the 10-year design storm event. The channel immediately below the pond outfall shall be modified to prevent erosion and conform to natural dimensions in the shortest possible distance. This is typically done by placing appropriately sized riprap, over filter fabric, which can reduce flow velocities from the principal spillway to non-erosive levels (3.5 to 5.0 fps depending on the channel lining material). Flared pipe sections that discharge at or near the stream invert or into a step pool arrangement shall be used at the spillway outlet.

Inlet areas shall be stabilized to ensure that non-erosive conditions exist during storm events up to the overbank flood event (i.e., the 10-year storm event). Inlet pipe inverts should generally be located at or slightly below the forebay pool elevation.

On-Line ED Ponds shall be designed to detain the required T_v and either manage or be capable of safely passing larger storm events conveyed to the pond (e.g., 10-year flood protection, and/or the 100-year design storm event).

Internal Design Features

Side slopes leading to the ED pond should generally have a gradient of 4H:1V to 5H:1V. The mild slopes promote better establishment and growth of vegetation and provide for easier maintenance and a more natural appearance.

ED pond designs shall have an irregular shape and a long flow path from inlet to outlet to increase water residence time, treatment pathways, and pond performance. In terms of flow path geometry, there are two design considerations: (1) the overall flow path through the pond, and (2) the length of the shortest flow path (Hirschman et al., 2009):

- ❖ The overall flow path can be represented as the length-to-width ratio OR the flow path. These ratios shall be at least 3L:1W. Internal berms, baffles, or topography can be used to extend flow paths and/or create multiple pond cells.
- ❖ The shortest flow path represents the distance from the closest inlet to the outlet. The ratio of the shortest flow to the overall length shall be at least 0.7. In some cases – due to site geometry, storm sewer infrastructure, or other factors – some inlets may not be able to meet these ratios. However, the drainage area served by these "closer" inlets shall constitute no more than 20% of the total contributing drainage area.

The total T_v storage may be provided by a combination of the permanent pool (in the form of forebays, deep pools, and/or wetland area) and extended detention storage.

The maximum T_v ED water surface elevation may not extend more than 4 feet above the basin floor or normal pool elevation. The maximum vertical elevation for ED detention over shallow wetlands is 1 foot. Frequent fluctuations in water elevations, or bounce effect, are not as critical for larger flood control storms (e.g., the 10-year design storm), and these events can exceed the 4-feet vertical limit if they are managed by a multi-stage outlet structure.

Safety features shall include the following:

- The principal spillway opening shall be designed and constructed to prevent access by small children.
- End walls above pipe outfalls greater than 48 inches in diameter shall be fenced to prevent a hazard.
- An emergency spillway and associated freeboard shall be provided in accordance with applicable local or state dam safety requirements. The emergency spillway shall be located so that downstream structures will not be impacted by spillway discharges.
- Both the safety bench and the aquatic bench shall be landscaped with vegetation that hinders or prevents access to the pool.

Landscaping and Planting Plan

A landscaping plan shall be provided that indicates the methods used to establish and maintain vegetative coverage within the ED pond. For more guidance on planting trees and shrubs in ED ponds consult Cappiella et al (2006). Minimum elements of a plan include the following:

- Delineation of pond-scaping zones within the pond
- Selection of corresponding plant species
- The planting plan
- The sequence for preparing the wetland bed, if one is incorporated with the ED pond (including soil amendments, if needed)
- Sources of plant material
- The planting plan shall allow the pond to mature into a native forest in the right places but keep mowable turf along the embankment and all access areas. The wooded wetland concept proposed by Cappiella et al., (2005) may be a good option for many ED ponds.
- Woody vegetation may not be planted or allowed to grow within 15 feet of the toe of the embankment nor within 25 feet from the principal spillway structure.
- Avoid species that require full shade or are prone to wind damage. Extra mulching around the base of trees and shrubs is strongly recommended as a means of conserving moisture and suppressing weeds.

Maintenance Reduction Features

Good maintenance access is needed so crews can remove sediments from the forebay, alleviate clogging, and make riser repairs. The following ED pond maintenance issues can be addressed during design, in order to make on-going maintenance easier:

- Adequate maintenance access shall extend to the forebay, micropool, any safety benches, riser, and outlet structure and shall have sufficient area to allow vehicles to turn around.
- The riser shall be located within the embankment for maintenance access, safety, and aesthetics.
- Access roads shall (1) be constructed of load-bearing materials or be built to withstand the expected frequency of use, (2) have a minimum width of 12 feet, and (3) have a profile grade that does not exceed 15%. Steeper grades are allowable if appropriate stabilization techniques are used, such as a gravel road.
- A maintenance right-of-way or easement shall extend to the ED pond from a public or private road.

ED Pond Material Specifications

ED ponds are generally constructed with materials obtained on-site, except for the plant materials, inflow and outflow devices (e.g., piping and riser materials), possibly stone for inlet and outlet stabilization, and filter fabric for lining banks or berms.

Emergency spillways shall be sized for any overtopping of pond in case of rain event in excess of 100-year storm and for instances of malfunction or clogging of primary outlet structure.

6.15.4 Construction, Protection, and Maintenance Requirements

All GIPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all GIPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For City policies, additional guidance, and forms pertaining to GIP protection, inspection, and maintenance requirements, see Appendix B of this manual.

Requirements During Construction

- A dense and vigorous vegetative cover, or other effective soil stabilization practice, shall be established over the contributing pervious drainage areas before storm water can be accepted into the ED pond. This will prevent sediment from accumulating in the basin.

Protection Requirements

- Provide signage for the GIP.
  - Allows for easy identification and location of the GIP.
  - Serves as a general education tool, making those responsible for property, landscape or GIP maintenance, and the general public aware of the water quality features of the GIP and to avoid encroachment.
- Design the layout of the ED pond such that maintenance access can be achieved without the need for vehicles or equipment in the storm water treatment area.

Inspection Requirements

- Inspect the areas where storm water flows into or out of the ED pond for clogging or sediment buildup.
- Inspect trees, shrubs, and other vegetation to ensure they meet landscaping and vegetation specifications. Replace if necessary.
- Inspect the property that drains to the ED pond for erosion, exposed soil, or stockpiles of other potential pollutants.

Maintenance Requirements

- Perform weeding, pruning, and trash removal as needed to maintain appearance.
- Inspect vegetation to evaluate health, replace if necessary.
- Keep inlets clear of debris to prevent clogging, clear if necessary.
- Inspect ED pond area for sediment build up, erosion, vegetative health/conditions, etc. Perform appropriate maintenance as necessary.

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6.16 Storm Water Wetland/Gravel Wetland

Storage Reuse | 80% TSS Removal

Figure 6.16.1. Example of Storm Water Wetland

DEVELOPMENT ATTRIBUTES

Construction Cost	LOW
Operation and Maintenance Cost	MODERATE
Ground-Level Encroachment	HIGH
Building Footprint Enhancement	HIGH
Triple Bottom-Line Benefits	MODERATE

Description:

Storm water wetlands are an engineered and constructed wetland system that is used for storm water management, primarily for pollutant removal. Runoff volume is stored and treated through natural filtration and biological uptake in the wetland GIP before discharge.

Variations:

- Shallow wetland
- Extended detention (ED) shallow wetland
- Basin/wetland system
- Pocket wetland
- Submerged gravel wetland

Key Advantages:

- Good nutrient removal
- Provides natural wildlife habitat
- Relatively low maintenance costs

Key Limitations:

- Requires large land area
- Needs continuous baseflow for viable wetland
- Regular sediment removal is critical to sustain wetlands

PERFORMANCE STANDARD COMPLIANCE					
Water Quality			Stream Channel Protection	Overbank Flood Protection	Extreme Flood Protection
Treatment Volume		80% TSS Removal			
Level 1	Level 2				
Not Approved	Not Approved	✓	✓	▶	▶

✓ Suitable for this practice

▶ Provides partial benefits

6.16.1 General Application

Storm water wetlands (also referred to as constructed wetlands) are constructed shallow marsh systems that are designed to both treat urban storm water and control runoff volumes. As storm water runoff flows through the wetland GIP, pollutant removal is achieved through settling and uptake by marsh vegetation. Wetlands can be utilized effectively for pollutant removal and also offer aesthetic value and wildlife habitat.

Constructed storm water wetlands differ from natural wetland systems in that they are engineered facilities designed specifically for treating storm water runoff and typically have less biodiversity than natural wetlands both in terms of plant and animal life. However, as with natural wetlands, storm water wetlands require a continuous base flow or a high-water table to support aquatic vegetation. There are several design variations of the storm water wetland, each design differing in the relative amounts of shallow and deep water, and dry storage above the wetland. The variations are shown in **Figure 6.16.2**. These include the shallow wetland, the extended detention shallow wetland, basin/wetland system, pocket wetland, and submerged gravel wetland.

Figure 6.16.2 Storm Water Wetland Variations

Shallow Wetland

Extended Detention Shallow Wetland

Pocket Wetland

Submerged Gravel Wetland

- **Shallow Wetland** – In the shallow wetland design, most of the water quality treatment volume is in the relatively shallow high marsh or low marsh depths. The only deep portions of the shallow wetland design are the forebay at the inlet to the wetland and the micropool at the outlet. One disadvantage of this design is that, since the pool is very shallow, a relatively large amount of land is typically needed to store the water quality volume.

- **Extended Detention (ED) Shallow Wetland** – The extended detention (ED) shallow wetland design is the same as the shallow wetland; however, part of the water quality treatment volume is provided as extended detention above the surface of the marsh and released over a period of 24 hours. This design can treat a greater volume of storm water in a smaller space than the shallow wetland design. In the extended detention shallow wetland option, plants that can tolerate both wet and dry periods need to be specified in the ED zone.

- **Basin/Wetland System** – The basin/wetland system has two separate cells: a wet basin and a shallow marsh. The wet basin traps sediments and reduces runoff velocities prior to entry into the wetland, where storm water flows receive additional treatment. Less land is required for a basin/wetland system than for the shallow wetland or the ED shallow wetland systems.

- **Pocket Wetland** – A pocket wetland is intended for smaller drainage areas of 5 to 10 acres and typically requires excavation down to the water table for a reliable water source to support the wetland system.
- **Submerged gravel wetland**- A system that consists of one or more treatment cells that are filled with crushed rock or gravel and is designed to allow storm water to flow subsurface through the root zone of the constructed wetland. The outlet from each cell is set at an elevation to keep the rock or gravel submerged. Wetland plants are rooted in the media where they can directly take up pollutants. In addition, algae and microbes thrive on the surface area of the rocks. In particular, the anaerobic conditions on the bottom of the filter can foster the denitrification process. Although widely used for wastewater treatment in recent years, only a handful of submerged gravel wetland systems have been designed to treat storm water. Mimicking the pollutant removal ability of nature, this structural control relies on the pollutant-stripping ability of plants and soils to remove pollutants from runoff. Submerged gravel wetland systems are not recommended for general application use to meet storm water management goals due to limited performance data. They may be applicable in special or retrofit situations where there are severe limitations on what can be implemented. Submerged gravel wetlands are generally applied to sites that have greater than 75% impervious cover.

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6.16.2 Planning and Physical Feasibility

The following feasibility issues need to be evaluated when storm water wetlands or submerged gravel wetlands are considered for a development site. Many of these issues will be influenced by the type of wetland system being considered. The following criteria provided it **Table 6.16.1** shall be considered when evaluating the suitability of a storm water wetland or submerged gravel wetland for a development site.

Table 6.16.1. Storm Water Wetland Constraints

Contributing Drainage Area	Hotspot Land Uses	Hydraulic Head Needed	Karst Areas	Pre-Treatment
Positive water balance needed to maintain wetland conditions. Storm water wetland shall be sized to 2 to 3% of the contributing drainage area. 5 acres max. for submerged gravel wetlands.	If a submerged gravel wetland receives hotspot runoff and has an underlying water supply aquifer, a separation distance of 2 feet is required between the bottom of the gravel and the elevation of the seasonally high water table.	Enough elevation drop is required, from inlet to outlet, to allow hydraulic conveyance by gravity.	Liner required.	Submerged gravel wetland designs shall include a sediment forebay or other equivalent pre-treatment measures to prevent sediment or debris from entering and clogging the gravel bed.
Setbacks	**Soils Requirement**	**Space Required**	**Water Table Requirement**	
Property lines require 10'. Septic systems require 50'. Private wells require 100 feet. Public water supply wells require 1,200 feet.	Geotechnical tests required. Liner, high water table, or soil conditions shall be present to maintain wetland conditions. Submerged gravel wetlands not recommended for clay/silt drainage areas that are not stabilized.	3 to 5% of the tributary drainage area. For submerged gravel wetlands, requirement depends on drainage area and available head	Impermeable liner, or min. separation of 2-4' required for portions of the wetland that will have standing water if there is a sensitive underlying aquifer.	

The data listed below is necessary for the design of a storm water wetland and shall be included with the development plan. See Appendix B for more information on required elements for the storm water management plan (SWMP).

- Existing and proposed site, topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Water surface elevation of nearby water systems as well as the depth to seasonally high groundwater.
- If no underdrain is proposed for the storm water wetland, then infiltration testing of native soils at proposed elevation of bottom of wetland area is required. See Appendix E for more information.
- If no underdrain is proposed, then the Infiltration Feasibility form provided in Appendix B shall be submitted with the SWMP.

6.16.3 Design Requirements

The storm water wetland shall be sized to 2 to 3% of the contributing drainage area. Storm water wetlands may be allowed for smaller drainage areas when water availability can be confirmed (such as from a groundwater source or areas that typically have a high water table). Wetlands that serve smaller drainage areas shall have an adequate anti-clogging device provided for the wetland outlet.

A continuous base flow or high water table is required to support wetland vegetation. A water balance shall be performed to demonstrate that a storm water wetland can withstand a 30-day drought at summer evaporation rates without completely drawing down.

When determining an appropriate location for a storm water wetland, the site designer shall also consider the location and use of other site features such as natural depressions, buffers, and undisturbed natural areas. The site designer should attempt to aesthetically "fit" the wetland into the landscape.

Storm water wetlands shall not be located in a stream or any other navigable waters of the United States, including natural (i.e., not constructed) wetlands. Where an appeal or variance of this policy is desired, the property owner shall obtain coverage under a Section 404 permit under the Clean Water Act and/or any applicate state or local permits and provide proof of such coverage with the Development Plan. The local jurisdiction may approve the conversion of an existing degraded wetland into a storm water wetland where appropriate for local watershed restoration efforts, and when prior approval for such a conversion is obtained from all applicable State and Federal agencies.

Each storm water wetland shall be placed in an easement that is recorded with the deed. The easement shall be defined at the outer edge of the aquatic bench if an aquatic bench is included in the basin design. The easement is to include the dam, all outlet devices, and the area 10 feet from the downstream toe of the dam.

A storm water wetland shall consist of the following elements, designed in accordance with the specifications provided in this section.

- Shallow marsh areas of varying depths with wetland vegetation;
- Permanent micropool;
- Overlying zone in which runoff control volumes are stored if the wetland will be used for storage of the CPv and the locally regulated peak discharge.
- Emergency spillway;
- Maintenance access;
- Sediment forebay at each wetland inlet (unless the inlet provides less than 10% of the total inflow to the wetland);
- Wetland buffer (this is not the same as a regulatory vegetated buffer - see section below on landscaping for more information); and
- Appropriate wetland vegetation and native landscaping.

Basin/wetland systems also include storm water basin facilities that shall meet all of the design parameters in Chapter 6, Section 14 for basin design.

In general, wetland designs are unique for each site and application. However, there are a number of geometric ratios and limiting depths for the design of a storm water wetland that shall be observed for adequate pollutant removal, ease of maintenance, and improved safety. **Table 6.16.2** provides the recommended physical specifications and geometry for the various storm water wetland design variants.

The storm water wetland shall be designed with the recommended proportion of "depth zones." Each of the four wetland design variants has depth zone allocations which are given as a percentage of the storm water wetland surface area. Target allocations are found in Table 6.16.2.

The four basic depth zones are:

- **Deepwater zone:** From 1.5 to 6 feet deep. Includes the outlet micropool and deepwater channels through the wetland GIP. This zone supports little emergent wetland vegetation but may support submerged or floating vegetation.
- **Low marsh zone:** From 6 to 18 inches below the normal permanent pool or water surface elevation. This zone is suitable for the growth of several emergent wetland plant species.
- **High marsh zone:** From 6 inches below the pool to the normal pool elevation. This zone will support a greater density and diversity of wetland species than the low marsh zone. The high marsh zone shall have a higher surface area to volume ratio than the low marsh zone.
- **Semi-wet zone:** Those areas above the permanent pool that are inundated during larger storm events. This zone supports several species that can survive flooding.

Table 6.16.2. Recommended Design Criteria for Storm Water Wetlands

Design Criteria	Shallow Wetland	ED Shallow Wetland	Basin/ Wetland	Pocket Wetland
Length to Width Ratio (minimum)	2:1	2:1	2:1	2:1
Extended Detention (ED)	No	Yes	Optional	Optional
Allocation of Tv_{TSS} Volume (pool/marsh/ED) in %	25/75/0	25/25/50	70/30/0 (includes basin volume)	25/75/0
Allocation of Surface Area (deepwater/low marsh/high marsh/semi-wet)[1] in %	20/35/40/5	10/35/45/10	45/25/25/5 (includes basin surface area)	10/45/40/5
Forebay	Required	Required	Required	See below
Micropool	Required	Required	Required	Required
Temporary Ponding Depth	15 inches	15 inches	15 inches	15 inches
Draw down time for large storms (to Tv_{TSS})	24 hours	24 hours	24 hours	24 hours
Outlet Configuration	Broad-crested weir	Broad-crested weir	Broad-crested weir	Broad-crested weir

<u>Depth Considerations:</u>
Deepwater: 1.5 to 6 feet below normal pool elevation
Low marsh: 6 to 18 inches below normal pool elevation
High marsh: 6 inches or less below normal pool elevation
Semi-wet zone: Above normal pool elevation

A dry weather flow path shall be provided from inflow to outlet across the storm water wetland. The path shall have a minimum length to width ratio of 2:1. Ideally, the path length to width ratio should be greater than 3:1. This path may be achieved by constructing internal dikes or berms, using marsh plantings, and/or by using multiple cells. Finger dikes are commonly used in surface flow systems to create serpentine configurations and prevent short-circuiting. Microtopography (contours along the bottom of a wetland or marsh that provide a variety of conditions for different species needs and increases the surface area to volume ratio) is encouraged to enhance wetland diversity.

A micropool having a depth no greater than 4 to 6 feet shall be included in the design at the outlet to prevent outlet clogging and re-suspension of sediments, and to mitigate thermal effects.

Maximum depth of any permanent pool areas shall not exceed 6 feet.

The volume that is handled through extended detention shall not comprise more than 50% of the total Tv_{TSS}, and its maximum water surface elevation shall not extend more than 3 feet above the normal pool. Storage of CPv and the locally regulated peak discharge can be provided above the maximum Tv_{TSS} elevation within the wetland.

The perimeter of all deep pool areas (4 feet or greater in depth) shall be surrounded by aquatic benches similar to those for storm water basins (see Chapter 6, Section 14).

The contours of the wetland shall be irregular to provide a more natural landscaping effect.

Use of the following design procedure forms are recommended when designing a storm water wetland. Proper use and completion of the form may allow a faster review of the development plan.

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Table 6.16.3. Design Procedure Form: Storm Water Wetlands

PRELIMINARY HYDROLOGIC CALCULATIONS

1a. Compute Tv_{TSS} — Tv_{TSS} = ___________ acre-ft

e-ft

1b. Compute CPv — CPv = ___________ acre-ft

STORMWATER WETLAND DESIGN

2. Is the use of a stormwater wetland appropriate? — ***See subsections 4.3.4.4 and 4.3.4.5 - A***

3. Confirm design criteria and applicability. — ***See subsection 4.3.4.5 - J***

4. Pretreatment Volume (Forebay)
   V_{pre} =(I)(.1")(1'/12") — V_{pre} = ___________ acre-ft

5. Shallow Wetland
   $V_{pool} = 0.2(Tv_{TSS}) - V_{pre}$
   $V_{marsh} = 0.7(Tv_{TSS}) - V_{pre}$

   Vol_{pool}= ___________ acre-ft
   Vol_{marsh}= ___________ acre-ft

   Shallow ED Wetland
   $V_{pool} = 0.1(Tv_{TSS}) - V_{pre}$
   $V_{marsh} = 0.3(Tv_{TSS}) - Vol_{pre}$
   $V_{ED} = 0.5(Tv_{TSS}) - Vol_{pre}$

   Vol_{pool}= ___________ acre-ft
   Vol_{marsh}= ___________ acre-ft
   Vol_{ED}= ___________ acre-ft

   Pocket Wetland
   $V_{pool} = 0.1(Tv_{TSS}) - V_{pre}$
   $V_{marsh} = 0.8(Tv_{TSS}) - V_{pre}$

   Pocket Wetland
   Vol_{pool}= 0.1(WQv)-Vol_{pre}
   Vol_{marsh}= 0.8(WQv)-Vol_{pre}

   Vol_{pool}= ___________ acre-ft
   Vol_{marsh}= ___________ acre-ft

6. Allocation of Surface Area

   Pool/Deepwater Wetland Zone (1.5-6 feet deep) — $Area_{water}$= ___________ acres, %= ___________
   Low Marsh Wetland Zone (6-18 inches deep) — $Area_{low}$= ___________ acres, %= ___________
   High Marsh Wetland Zone (0-6 inches deep) — $Area_{high}$= ___________ acres, %= ___________
   Semi-Wet Wetland Zone (above pool depth) — $Area_{semi}$= ___________ acres, %= ___________
   100.00%

7. Conduct grading and determine storage available for marsh zones (and ED if applicable), and compute orifice size for peak flow control per local regulations

   Prepare an elevation-storage table and curve using the average area method for computing volumes. Size orifices by routing.

Elevation MSL	Area ft^2	Ave. Area ft^2	Depth ft	Volume ft^3	Cumulative Volume ft^3	Cumulative Volume acre-ft	Volume above Permanent Pool acre-ft

8. Check inlet condition
   Check outlet conditions

   Use culverty design guidance from local municipality

9. Size emergency spillway using the local municipality peak discharge and set top of embankment elevation and emergency spillway elevation based on $WSEL_{peak}$

   $Q_{ES}=Qp_{peak}$ ___________ cfs
   $WSEL_{peak}$= ___________ ft
   El_{embank}= ___________ ft
   El_{ES}= ___________ ft

10. Verify peak flow control, water quality drawdown time and channel protection detention time

The designer shall calculate CP_v, Q_{p25}, and Q_f, in accordance with the guidance presented in Chapter 4.

Then the designer shall determine pretreatment volume. A sediment forebay is provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the basin. The forebay shall be sized to contain 0.1 inch per impervious acre of contributing drainage.

Then the designer shall design the emergency overflow system. Calculate the 100-year water surface elevation, set the top of the embankment elevation, and analyze safe passage of the Q_f. Set the invert elevation of the emergency spillway 0.1 foot above the 100-year water surface elevation.

Then the designer shall set up a stage-storage-discharge relationship for the control structure for the 25- and 100-year, 24-hour storm orifices to design embankment(s) and spillway(s).

Sizing of Storm Water Wetlands

Storm Water Quality

Designers can use a site-adjusted R_v (see Chapter 4), which reflects the use of upland runoff reduction practices, to compute the remaining treatment and flood protection volumes that shall be treated by the storm water wetland or submerged gravel wetland. Storm water wetlands shall then be designed to capture and treat the remaining runoff volume as necessary, using methodology found below and in Chapter 4. The water quality treatment approach shall be calculated by Equation 1.

Equation 1. Water Quality Volume

$$WQ_V = (1.2)\ (RV)\ (A)\ /\ 12$$

Where:

WQ_V = Water Quality Volume (ft.^{3})

1.2 = Target rainfall amount to be treated (inches)

RV = Volumetric runoff coefficient which can be found by: $RV = 0.05+0.009(I)$

Where:

I = new impervious area of the contributing drainage area (%)

A = Area draining to this practice (ft.^{2})

12 = Unit conversion factor (in/ft.)

Once the low flow orifice has been sized, design embankments and emergency spillways, investigate potential dam hazard classifications, and finally design inlets, sediment forebays, outlet structures, maintenance access, and safety features. These items are detailed in below.

Required Geotechnical Testing

Soil borings shall be taken below the proposed embankment, in the vicinity of the proposed outlet area, and in at least two locations within the proposed storm water wetland area. Soil boring data is needed to (1) determine the physical characteristics of the excavated material, (2) determine its adequacy for use as structural fill or spoil, (3) provide data for structural designs of the outlet works (e.g., bearing capacity and buoyancy), (4) determine compaction/composition needs for the embankment, (5) determine the depth to groundwater and bedrock, and (6) evaluate potential infiltration losses (and the potential need for a liner).

Pre-Treatment

Sediment forebays are considered to be an integral design feature for storm water wetlands. A forebay shall be located at each major inlet to trap sediment and preserve the capacity of the main treatment cell. Other forms of pre-treatment for sheet flow and concentrated flow for minor inflow points shall be designed consistent with pre-treatment criteria found in Chapter 6, Section 3.

The following criteria apply to forebay design:

- Sediment regulation and removal is critical to sustain storm water wetlands. A wetland GIP shall have a sediment forebay or equivalent upstream pretreatment. In some cases, a pocket wetland design may not allow construction of a sediment forebay because of space limitations on small sites. In this case, a smaller "cattail" forebay is recommended to capture trash, debris, and oil.
- A sediment forebay is designed to remove incoming sediment from the storm water flow prior to dispersal into the wetland. The forebay shall consist of a separate cell, formed by an acceptable barrier. A forebay shall be provided at each inlet unless the inlet provides less than 10% of the total design storm inflow to the wetland GIP.
- The forebay shall be sized to contain 0.1 inches per impervious acre (363 ft^3) of contributing drainage and shall be no more than 4 to 6 feet deep. The pre-treatment storage volume is part of the total T_{vTSS} design requirement and may be subtracted from the T_{vTSS} for wetland storage sizing.
- The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.
- Inflow channels shall be stabilized with flared riprap aprons, or the equivalent. Inlet pipes to the basin can be partially submerged. Exit velocities from the forebay to the wetland shall be nonerosive.

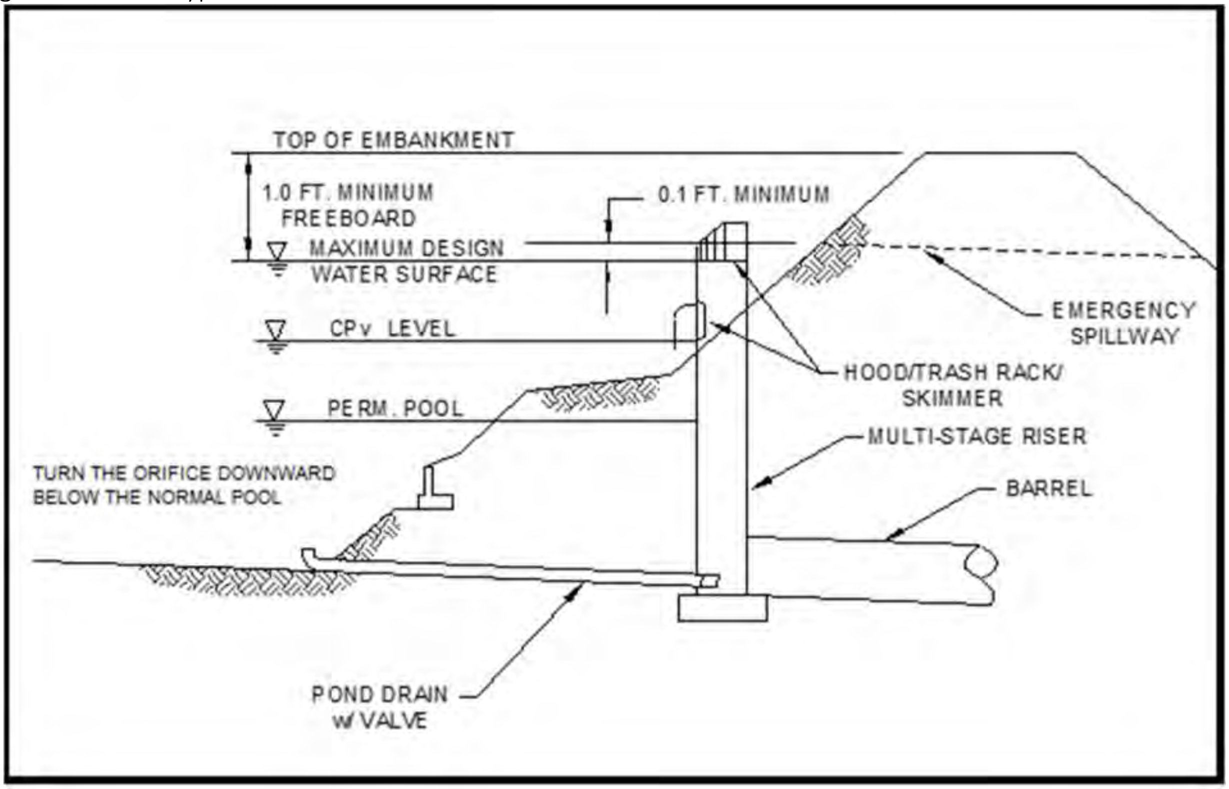
Pre-treatment is also required for submerged gravel wetlands and shall include the following:

- Sediment regulation and removal is critical to sustain submerged gravel wetlands. A gravel wetland facility shall have a sediment forebay or equivalent upstream pretreatment.
- A sediment forebay is designed to remove incoming sediment from the storm water flow prior to dispersal into the wetland. The forebay shall consist of a separate cell, formed by an acceptable barrier. A forebay shall be provided at each inlet unless the inlet provides less than 10% of the total design storm inflow to the gravel wetland facility.
- The forebay shall be sized to contain 0.1 inches per impervious acre (363 ft^3) of contributing drainage and shall be no more than 4 to 6 feet deep. The pretreatment storage volume is part of the total Tv_{TSS} design requirement and may be subtracted from the WQv for wetland storage sizing.
- Inflow channels shall be stabilized with flared riprap aprons, or the equivalent. Exit velocities from the forebay to the wetland shall be non-erosive.

Outlets

- Flow control from a storm water wetland is typically accomplished with the use of a concrete riser and barrel. The riser is a vertical pipe or inlet structure that is attached to the base of the micropool with a watertight connection. The outlet barrel is a horizontal pipe attached to the riser that conveys flow under the embankment (see **Figure 6.16.3**). The riser shall be located within the embankment for maintenance access, safety and aesthetics.

Figure 6.16.3. Typical GIP Outlet



- A number of outlets at varying depths in the riser provide internal flow control for routing of Tv_{TSS}, CPv, and the locally regulated peak discharge. The number of orifices can vary and is usually a function of the wetland design.
- For shallow and pocket wetlands, the riser configuration is typically comprised of a channel protection outlet (usually an orifice) and overbank flood protection outlet (often a slot or weir). The channel protection orifice is sized to release the channel protection storage volume over a 24-hour period. Since the water quality volume is fully contained in the permanent pool, no orifice sizing is necessary for this volume. As runoff from a water quality event enters the wet basin, it simply displaces that same volume through the channel protection orifice. Thus, an off-line shallow or pocket wetland providing only water quality treatment can use a simple overflow weir as the outlet structure.
- In the case of an extended detention (ED) shallow wetland; there is generally a need for an additional outlet (usually an orifice) that is sized to pass the extended detention water quality volume that is surcharged on top of the permanent pool. Flow will first pass through this orifice, which is sized to release the water quality ED volume in 24 hours. The next outlet is sized for the release of the channel protection storage volume. The outlet (often an orifice) invert is located at the maximum elevation associated with the extended detention water quality volume and is sized to release the channel protection storage volume over a 24-hour period.
- Alternative hydraulic control methods to an orifice can be used and include the use of a broad-crested rectangular, V-notch, proportional weir.
- The water quality outlet (if design is for an ED shallow wetland) and channel protection outlet shall be fitted with an adjustable orifice to be used to adjust detention time.
- Higher flows (locally regulated peak discharge) pass through openings or slots protected by trash racks that are located further up on the riser.

- After entering the riser, flow is conveyed through the barrel and is discharged downstream.
- Riprap, plunge pools, pads, or other energy dissipators shall be placed at the outlet of the barrel to prevent scouring and erosion. If a wetland GIP discharges to a stream that has dry weather flow at any time during the year, care shall be taken to minimize land disturbance along the downstream channel and to reestablish a (forested) vegetated buffer in the shortest possible distance.
- The wetland GIP shall have a bottom drain pipe located in the micropool with a plug valve that can completely or partially drain the wetland within 24 hours.
- The wetland drain shall be sized one pipe size greater than the calculated design diameter. The drain valve is a handwheel activated plug valve. Valve controls shall be located inside of the riser at a point where they (a) will not normally be inundated and (b) can be operated in a safe manner.

See the typical details in Appendix F as well as Common Components in Chapter 6, Section 2 for additional information and specifications on basin routing and outlet operations.

For submerged gravel wetlands, an outlet pipe shall be provided from the submerged gravel wetland to the facility discharge. The design shall ensure that the discharges occur in a non-erosive manner.

Safety features shall include the following:

- Fencing of wetlands is not generally desirable. A preferred method to promote safety is to manage the contours of deep pool areas.
- All outlet structures shall be designed so as not to permit access by children.

Landscaping and Planting Plan

A landscaping plan shall be provided that indicates the methods used to establish and maintain wetland coverage. For more guidance refer to Appendix C. Minimum elements of a plan include the following:

- Delineation of landscaping zones, selection of corresponding plant species, planting plan, sequence for preparing wetland bed (including soil amendments, if needed), and sources of plant material.
- Landscaping zones include low marsh, high marsh, and semi-wet zones. The low marsh zone ranges from 6 to 18 inches below the normal pool. This zone is suitable for the growth of several emergent plant species. The high marsh zone ranges from 6 inches below the pool up to the normal pool. This zone will support greater density and diversity of emergent wetland plant species. The high marsh zone shall have a higher surface area to volume ratio than the low marsh zone. The semi-wet zone refers to those areas above the permanent pool that are inundated on an infrequent basis and can be expected to support wetland plants.
- The landscaping and planting plan shall provide elements that promote greater wildlife and waterfowl use within the wetland and buffers.
- Woody vegetation shall not be planted on the embankment or allowed to grow within 15 feet of the toe of the embankment and 25 feet from the principal spillway structure.
- Existing trees shall be preserved in the wetland area during construction if possible or shall be replanted. It is desirable to locate forest conservation areas adjacent to wetlands. To discourage resident waterfowl populations, the wetland buffer can be planted with trees, shrubs and native ground covers.

- The soils in planting areas within and surrounding a wetland are often severely compacted during the construction process to ensure stability. The density of these compacted soils is so great that it effectively prevents root penetration and therefore may lead to premature mortality or loss of vigor. Consequently, it is required to excavate holes around the proposed planting sites and backfill these with uncompacted topsoil.
- Native species of fish can be stocked in the permanent pool to aid in mosquito prevention. The use of non-native fish species in a GIP is not permitted due to the possibility that the fish will enter downstream receiving waters.
- A fountain may be used for oxygenation of water in the permanent pool and to aid in mosquito breeding prevention.

Maintenance Reduction Features

Good maintenance access is needed so crews can remove sediments, alleviate clogging, and maintain vegetation. The following storm water wetland maintenance issues can be addressed during design, to make on-going maintenance easier:

- A minimum 20 ft. wide maintenance easement shall be provided from a public right-of-way. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.
- The maintenance access shall extend to the forebay, riser, and outlet, and, to the extent feasible, be designed to allow vehicles to turn around.
- Access to the riser shall be provided by a riser top used for overflow, and manhole steps within easy reach of valves and other controls.
- Each storm water wetland shall be placed in an easement that is recorded with the deed. The easement shall be defined at the outer edge of the wetland, all outlet devices, and the area 10 feet around these items.
- A maintenance right-of-way or easement shall extend to the storm water wetland from a public or private road.

Storm Water Wetland Specifications

Storm water wetlands are generally constructed with materials obtained on-site, except for the plant materials, inflow and outflow devices (e.g., piping and riser materials), possibly stone for inlet and outlet stabilization, and filter fabric for lining banks or berms.

Manufactured submerged gravel wetlands shall be selected based on good design, suitability for the desired pollution control goals, durability, ease of installation, ease of maintenance, and reliability.

Emergency spillways shall be sized for any overtopping of the pond in case of rain event in excess of 100-year storm and, for instances, of malfunction or clogging of primary outlet structure.

6.16.4 Construction, Protection, and Maintenance Requirements

All GIPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all GIPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For City policies, additional guidance, and forms pertaining to GIP protection, inspection, and maintenance requirements, see Appendix B of this manual.

Requirements During Construction

- A dense and vigorous vegetative cover shall, or other effective soil stabilization practice, be established over the contributing pervious drainage areas before storm water can be accepted into the storm water wetland. This will prevent sediment from accumulating in the basin.

- Submerged gravel wetlands are generally applied to sites that have greater than 75% impervious cover. Any disturbed or denuded areas located within the area draining to and treated by the submerged gravel wetland shall be stabilized prior to construction and use of the submerged gravel wetland.

Protection Requirements

- Provide signage for the GIP.
    - Allows for easy identification and location of the GIP.
    - Serves as a general education tool, making those responsible for property, landscape or GIP maintenance, and the general public aware of the water quality features of the GIP and to avoid encroachment.

- Design the layout of the storm water wetland or submerged gravel wetland such that maintenance access can be achieved without the need for vehicles or equipment in the storm water treatment area.

Inspection Requirements

- Inspect the areas where storm water flows into or out of the storm water wetland for clogging or sediment buildup.

- Inspect trees, shrubs, and other vegetation to ensure they meet landscaping and vegetation specifications. Maintain at least 50% coverage with vegetation. Check for invasive species. Replace vegetation if necessary.

- Inspect the property that drains to the storm water wetland for erosion, exposed soil, or stockpiles of other potential pollutants.

Maintenance Requirements

- Perform weeding, pruning, and trash removal as needed to maintain appearance.

- Remove invasive vegetation

- Inspect vegetation to evaluate health, replace if necessary.

- Keep inlets clear of debris to prevent clogging, clear if necessary.

- Monitor sediment accumulation and remove periodically from basins. Periodic sediment removal is required to prevent clogging of gravel base in submerged gravel wetlands.

- Inspect storm water wetland area for sediment build up, erosion, vegetative health/conditions, etc. perform appropriate maintenance as necessary.

6.17 Underground Detention

Figure 6.17.1. Underground Detention Construction

DEVELOPMENT ATTRIBUTES

Construction Cost	MODERATE
Operation and Maintenance Cost	LOW
Ground-Level Encroachment	LOW
Building Footprint Enhancement	LOW
Triple Bottom-Line Benefits	MODERATE

Description:

Detention storage located in underground tanks or vaults is designed to provide water quantity control through detention and/or extended detention of storm water.

Variations:

- Detention vaults
- Detention tanks
- Detention chambers
- Detention vaults with pre-treatment

Key Advantages:

- Ideal for highly urbanized areas where land is limited
- Can be used for storm water quantity control downstream of other runoff reducing or water quality treating GIPs
- Some designs require minimal drop between inlet and outlet

Key Limitations:

- Not designed to provide storm water quality benefits unless designed in series with other GIPs and pre-treatment is incorporated
- Underground installation may make these systems difficult to maintain
- Performance dependent on design and frequency of inspection and cleanout of unit
- Some designs may require a confined space entry for maintenance and repairs

PERFORMANCE STANDARD COMPLIANCE					
Water Quality			Stream Channel Protection	Overbank Flood Protection	Extreme Flood Protection
Treatment Volume		80% TSS Removal			
Level 1	Level 2				
Not Approved	Not Approved		✓	✓	✓

✓ Suitable for this practice

▶ Provides partial benefits

6.17.1 General Application

Detention vaults are box-shaped underground storm water storage facilities typically constructed with reinforced concrete. In contrast, detention tanks are underground storage facilities typically constructed with a large diameter metal or plastic pipe. Both serve as an alternative to surface detention for storm water quantity control, particularly for space-limited areas where there is not adequate land for a dry detention basin or multi-purpose detention area.

Both underground vaults and tanks can provide channel protection through extended detention of the channel protection volume (CP_v) and overbank flood Q_{p25} (and in some cases protection for the extreme flood Q_f). Basic storage design and routing methods are the same for detention basins except that a bypass for high flows is typically included.

Underground detention vaults and tanks are not intended for water quality treatment. Therefore, they shall be used in a treatment train approach with other BMPs and GIPs that provide treatment of the WQ_v with the underground vault or tank being the component that is downstream in the treatment train. This will prevent the underground vault or tank from becoming clogged with trash or sediment and significantly reduces the maintenance requirements for an underground detention system. It should be noted that some underground detention vaults and tanks can be designed with integrated pre-treatment.

Prefabricated concrete vaults are available for commercial vendors. In addition, several pipe manufacturers have developed packaged detention systems. **Figure 6.17.2** and **Figure 6.17.3** show example design schematics for underground detention systems.

Figure 6.17.2. Example Underground Detention Tank System *(Source: WDE, 2000)*

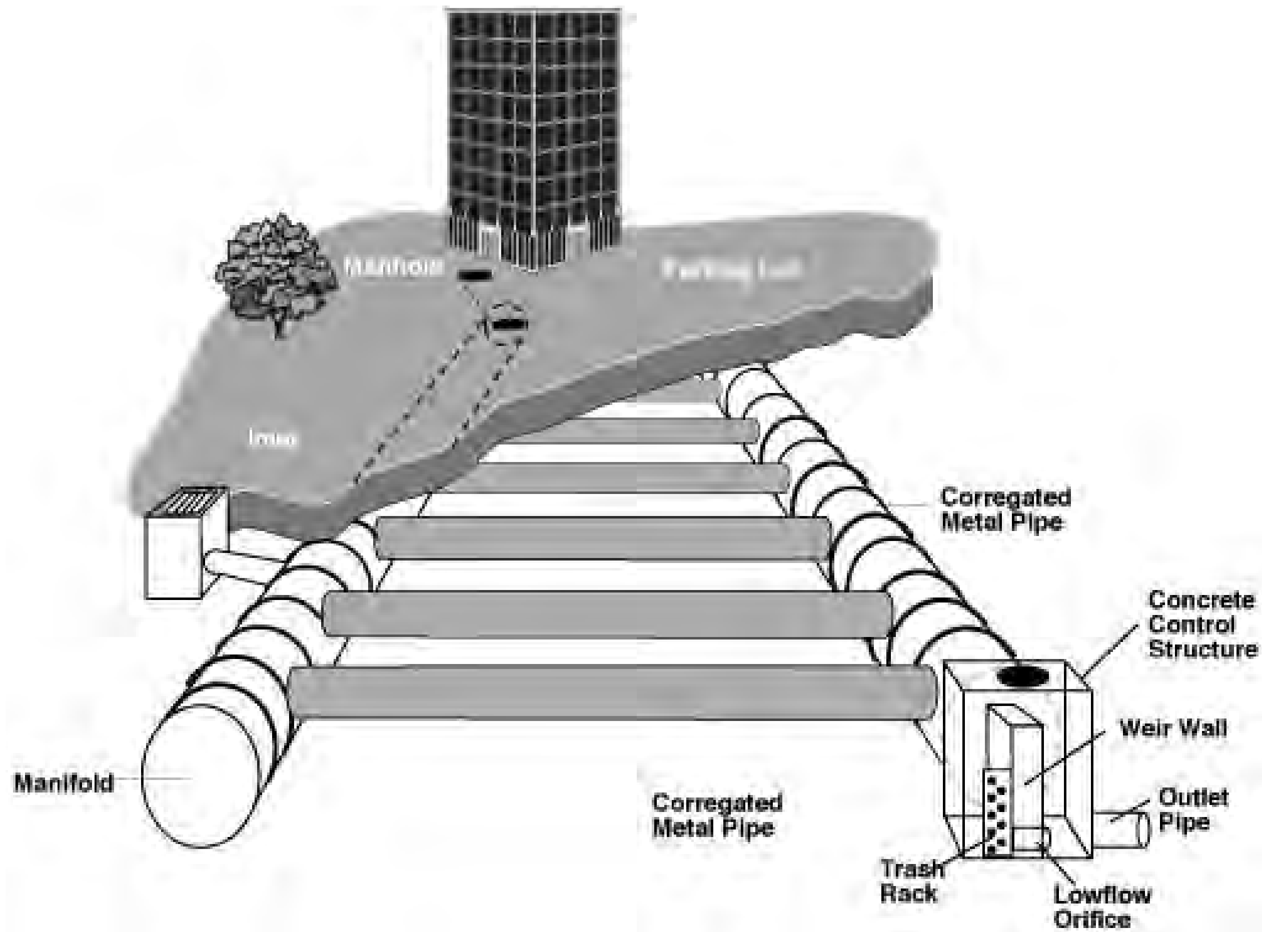
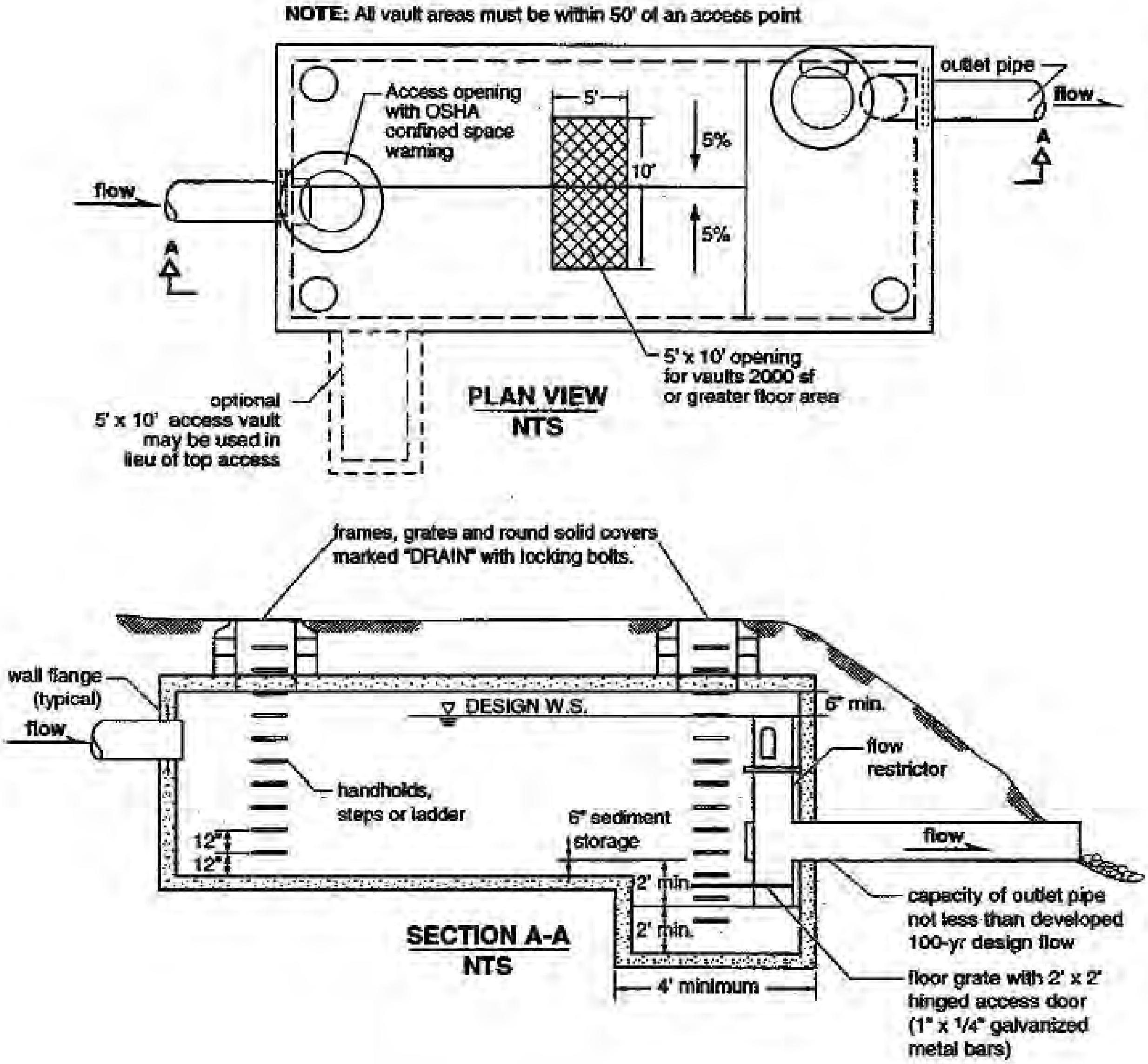


Figure 6.17.3. Example Underground Detention Tank System *(Source: WDE, 2000)*



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6.17.2 Planning and Physical Feasibility

The following feasibility issues need to be evaluated when underground detention is considered as the final practice in a treatment train. The following criteria provided in **Table 6.17.1** shall be considered when evaluating the suitability of underground detention for a development site.

Table 6.17.1. Underground Detention Constraints

Contributing Drainage Area	Hotspot Land Uses	Site Slope	Site Layout
25 acres max.	No constraints, well-suited for hot spot runoff.	Underground detention may be installed on sites with slopes up to 15%. Adequate maintenance access to each chamber shall be provided for inspection and cleanout of underground detention units.	Not allowed in areas where operation may create a risk for basement flooding, interfere with subsurface sewage disposal systems, or affect other underground structures. Overflow shall drain away from buildings to prevent damage to foundations.
Soils Requirement	**Space Required**	**Trout Streams**	
Infiltration and geotechnical tests required. Structural load bearing capacity of subsurface soils shall be adequate to support the detention device and storm water runoff.	Underground detention is installed underground; therefore, minimal surface area is required for the facility.	Not effective for protecting trout streams due to potential for thermal impacts, suspended solids, or soluble pollutants.	

The data listed below is necessary for the design of underground detention and shall be included with the development plan. See Appendix B for more information on required elements for the development plan.

- Existing and proposed site, topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Infiltration testing of native soils at proposed elevation of underground detention.
- Geotechnical and structural load bearing capacity of subsurface soils.

6.17.3 Design Requirements

The designer shall calculate CP_v, Q_{p25}, and Q_f, in accordance with the guidance presented in Chapter 4.

Then, the designer shall determine pretreatment volume. A separate sediment sump or vault chamber sized to 0.1 inches times the impervious acres of contributing drainage area shall be provided at the inlet for underground detention systems that are in a treatment train with off-line water quality treatment GIPs.

Then, the designer shall design the emergency overflow system. Set up a stage-storage-discharge relationship for the control structure for the 1-year, 24-hour rainfall event orifice. Size and determine the invert elevation of the CP_v orifice to ensure that the channel protection volume is stored for at least 24 hours within the underground detention facility. Then, the designer shall set up a stage-storage-discharge relationship for the control structure for the 25- and 100-year, 24-hour storm orifices to design embankment(s) and spillway(s).

Sizing of Underground Detention Practices

Storm Water Quality

Another BMP or GIP shall be used in a treatment train with underground detention to provide storm water quality as they are not designed to remove pollutants. In addition, some underground detention vaults and tanks can be designed with integrated pre-treatment and manufacturer's specifications shall be consulted.

Required Geotechnical Testing

Soil borings shall be taken in at least two locations within the proposed underground detention area. Soil boring data is needed to (1) determine the physical characteristics of the excavated material, (2) determine its adequacy for use as structural fill or spoil, (3) provide data for structural designs of the outlet works (e.g., bearing capacity and buoyancy), and (4) determine compaction/composition needs for the embankment.

Pre-Treatment

The pretreatment/inlet system shall meet the following specifications:

- A separate sediment sump or vault chamber sized to 0.1 inches times the impervious acres of contributing drainage shall be provided at the inlet for underground detention systems that are in a treatment train with off-line water quality treatment GIPs; and
- For CP_v control, a low-flow orifice capable of releasing the channel protection volume over 24 hours shall be provided. The channel protection orifice shall have a minimum diameter of 3 inches and be adequately protected from clogging by an acceptable external trash rack. The orifice diameter may be reduced to 1 inch if internal orifice protection is used (i.e., an over-perforated vertical stand pipe with 0.5 inches orifices or slots that are protected by wire cloth and a stone filtering jacket). Adjustable gate valves can also be used to achieve an equivalent diameter.

Conveyance and Overflow

The outlet structures shall meet the following specifications:

- For overbank flood protection, an additional outlet is sized for Qp25 control (based upon hydrologic routing calculations) and can consist of a weir, orifice, outlet pipe, combination outlet, or other acceptable control structure.
- Riprap, plunge pools or pads, or other energy dissipators shall be placed at the end of the outlet to prevent scouring and erosion.
- A high-flow bypass shall be included in the underground detention system design to safely pass the extreme flood flow (Qf).

Internal Design Features

The following criteria shall be considered **minimum** standards for the design of an underground detention system:

- Routing calculations shall be used to demonstrate that the storage volume is adequate.
- Underground detention vaults and tanks shall meet structural requirements for overburden support and traffic loading, if appropriate.

Safety features shall include the following:

- Maintenance activities for an underground detention device may require a confined space entry.
- Vaults that are greater than 4 feet deep shall be equipped with a safety ladder.
- A minimum 20-foot wide maintenance right-of-way or drainage easement shall be provided for the underground detention.

Maintenance Reduction Features

Good maintenance access is needed so crews can remove sediments, alleviate clogging, and make repairs. The following underground detention issues can be addressed during design in order to make on-going maintenance easier:

- Adequate maintenance access is required and shall have sufficient area to allow vehicles to turn around.
- Access roads shall (1) be constructed of load-bearing materials or be built to withstand the expected frequency of use, (2) have a minimum width of 12 feet, and (3) have a profile grade that does not exceed 15%. Steeper grades are allowable if appropriate stabilization techniques are used such as a gravel road.
- A maintenance right-of-way or easement shall extend to the underground detention from a public or private road.
- Adequate maintenance access shall be provided for all underground detention systems. Access shall be provided over the inlet pipe and outflow structure. Access openings shall consist of a standard frame, grate, and solid cover or a removable panel.
- Vaults with widths of 10 feet or less shall have removable lids.

Underground Detention Material Specifications

- Minimum 3,000 psi structural reinforced concrete shall be used for underground detention vaults. All construction joints shall be provided with water stops. Cast-in-place wall sections shall be designed as retaining walls.
- The minimum pipe diameter for underground detention tanks is 36 inches.
- The maximum depth from finished grade to the vault invert shall be 20 feet.

6.17.4 Construction, Protection, and Maintenance Requirements

All BMPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all BMPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For City policies, additional guidance, and forms pertaining to BMP protection, inspection, and maintenance requirements, see Appendix B of this manual.

Requirements During Construction

- Simple erosion and sediment control measures, such as temporary stabilization, silt fencing, and inlet protection, shall be used in areas of the site that drain to the underground detention.
- A dense and vigorous vegetative cover, or other effective soil stabilization practice, shall be established over the contributing pervious drainage areas before storm water can be accepted into the underground detention. This will prevent sediment from accumulating in the underground detention.

- Newly installed underground detention shall be inspected prior to being placed in service. Sediment and debris that may have collected in the system during delivery and installation shall be removed.

Protection Requirements

- Provide signage for the BMP.
    - Allows for easy identification and location of the BMP.
    - Serves as a general education tool, making those responsible for property, landscape or BMP maintenance, and the general public aware of the water quality features of the BMP and to avoid encroachment.
- Design the layout of the underground detention such that maintenance access can be achieved without the need for vehicles or equipment in the storm water treatment area.

Inspection Requirements

- Inspect the areas where storm water flows into or out of the underground detention for clogging or sediment buildup.
- Inspect the property that drains to the underground detention for erosion, exposed soil, or stockpiles of other potential pollutants.

Maintenance Requirements

- Remove any trash, debris, and sediment buildup in the underground vaults or tanks.
- Perform structural repairs to inlet and outlets, as needed.
- Follow manufacturer's instructions for additional maintenance requirements.

6.18 Sand Filter

Mechanical Filtration | 80% TSS Removal

Figure 6.18.1. Sand Filter

DEVELOPMENT ATTRIBUTES

Construction Cost	LOW
Operation and Maintenance Cost	HIGH
Ground-Level Encroachment	LOW
Building Footprint Enhancement	LOW
Triple Bottom-Line Benefits	LOW

Description:

A sand filter is a multi-chamber structure designed to treat storm water runoff through filtration, using a sediment forebay, a sand bed as its primary filter media, and, typically, an underdrain collection system.

Variations:

- Surface Sand Filter
- Perimeter Sand Filter

Key Advantages:

- Applicable to small drainage areas
- Good for highly impervious areas
- Good retrofit capability

Key Limitations:

- High maintenance burden
- Not recommended for areas with high sediment content in storm water or clay/silt runoff areas
- Relatively costly
- Possible odor problems

PERFORMANCE STANDARD COMPLIANCE

Water Quality			Stream Channel Protection	Overbank Flood Protection	Extreme Flood Protection
Treatment Volume		80% TSS Removal			
Level 1	Level 2				
Not Approved	Not Approved	✓	▶		

✓ Suitable for this practice

▶ Provides partial benefits

6.18.1 General Application

Sand filters (also referred to as filtration basins) are BMPs that capture and temporarily store storm water runoff and pass it through a filter bed of sand. Most sand filter systems consist of two-chamber structures. The first chamber is a sediment forebay or sedimentation chamber, which removes floatables and heavy sediments. The second is the filtration chamber, which removes additional pollutants by filtering the runoff through a sand bed. The filtered runoff is typically collected and returned to the conveyance system, though it can also be partially or fully exfiltrated into the surrounding soil in areas with porous soils.

Because they have few site constraints beside head requirements, sand filters can be used on development sites where the use of other structural controls may be precluded. However, sand filter systems can be relatively expensive to construct and maintain.

There are two primary sand filter system designs, the surface sand filter and the perimeter sand filter. Below are descriptions of these filter systems:

- **Surface Sand Filter** - The surface sand filter is a ground-level open air structure that consists of a pre-treatment sediment forebay and a filter bed chamber. This system can treat drainage areas up to 10 acres in size and is most commonly located off-line. Surface sand filters can be designed as an excavation with earthen embankments or as a concrete or block structure.
- **Perimeter Sand Filter -** The perimeter sand filter is an enclosed filter system typically constructed just below grade in a vault along the edge of an impervious area such as a parking lot. The system consists of a sedimentation chamber and a sand bed filter. Runoff flows into the structure through a series of inlet grates located along the top of the control.

A third design variant, the underground sand filter, is intended primarily for extremely space limited and highly dense areas. Underground sand filters require additional planning for access, maintenance, and incorporation with the storm water management plan.

Sand filter systems are designed primarily as off-line systems for storm water quality (i.e., the removal of storm water pollutants) and typically need to be used in conjunction with another GIP or BMP to provide downstream channel protection, overbank flood protection, and extreme flood protection, if required. However, under certain circumstances, filters can provide limited runoff quantity control, particularly for smaller storm events. If used for smaller drainage areas, or used to provide limited quantity control, sand filters could be used as an on-line system provided proper design planning for erosion and scour is considered.

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6.18.2 Planning and Physical Feasibility

The following feasibility issues need to be evaluated when sand filters are considered as the final practice in a treatment train. Many of these issues will be influenced by the type of sand filter being considered. The following criteria provided in **Table 6.18.1** shall be considered when evaluating the suitability of a sand filter for a development site.

Table 6.18.1. Sand Filter Constraints

Contributing Drainage Area	Hotspot Land Uses	Hydraulic Head needed	Impervious Area	Irrigation or Baseflow
10 acres max. for surface sand filters. 2 acres max. for perimeter sand filters.	Watertight polyliner or impermeable membrane required.	6 ft. for surface sand filters. 2-3 ft. for perimeter sand filters.	Adequate pre-treatment required for sites with < 50% imperviousness or high clay/silt sediment loads.	Typically, off-line systems. Not for use where there is continuous flow from groundwater, sump pumps, or other sources.
Landscaping	**Sand Filter Slope**	**Site Layout**	**Soils Requirement**	**Water Table Requirement**
Grass cover may be installed to aid in pollutant removal and prevent clogging. No other landscaping over the sand filter or in areas that will block maintenance access. No tree planting within 15 ft.	6% max. slope across filter location	Perimeter sand filters are typically sited along the edge, or perimeter, of an impervious area such as a parking lot.	No restrictions; Group "A" soils generally required to allow exfiltration (for surface sand filter earthen structure). Infiltration test required.	2 ft. of separation

The data listed below is necessary for the design of a sand filter and shall be included with the development plan. See Appendix B for more information on required elements for the development plan.

- Existing and proposed site, topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Water surface elevation of nearby water systems as well as the depth to seasonally high groundwater.
- Infiltration testing of native soils at proposed elevation of bottom of sand filter.

6.18.3 Design Requirements

Another BMP or GIP shall be used in a treatment train with sand filters to provide runoff reduction as they are not designed to provide RR_V as a stand-alone BMP.

Sizing of a Sand Filter

Storm Water Quality

Designers shall consider whether the sand filter is intended to just meet the 80% TSS removal target or be "oversized" to include partial credit for storage capacity for other storm water requirements (Channel Protection Volume (Cp_v)).

Equation 1. Target Water Quality Volume (Q_v)

$$WQ_V = (1.2)\,(R_V)\,(A)/12$$

Where:

- WQ_V = Water Quality Volume (ft.^{3})
- 1.2 = Target rainfall amount to be treated (in.)
- R_V = Volumetric runoff coefficient which can be found by: $R_V = 0.05+0.009(I)$

Where:

- I = new impervious area of the contributing drainage area (%)
- A = Area draining to this practice (ft.^{2})
- 12 = Unit conversion factor (in./ft.)

The peak rate of discharge for the water quality design storm is needed for sizing of off-line diversion structures. If designing off-line, then using WQv, compute CN, compute time of concentration using TR-55 method, determine appropriate unit peak discharge from time of concentration, and then compute Q_{wq} from unit peak discharge, drainage area, and WQ_v.

A flow diversion structure shall be sized, if needed. A flow regulator (or flow splitter diversion structure) shall be supplied to divert the WQ_v to the sand filter facility.

A low flow orifice, weir, or other device shall be designed to pass Q_{wq}.

The filter area is sized using **Equation 2** (based on Darcy's Law):

Equation 2. Area of Low Flow Orifice

$$A_f = (WQv)\,(d_f) \,/\, [(k)\,(h_f + d_f)\,(t_f)]$$

Where:

- A_f = surface area of filter bed (ft.^{2})
- d_f = filter bed depth (typically 18 in., no more than 24 in.)
- k = coefficient of permeability of filter media (ft./day) (use 3.5 ft./day for sand)
- h_f = average height of water above filter bed (ft.) (1/2 h_{max}, which varies based on site but hmax is typically ≤ 6 ft.)
- t_f = design filter bed drain time (days) (1.67 days or 40 hours is recommended maximum)

Set preliminary dimensions of filtration basin chamber.

See Chapter 4 for filter media specifications.

The sedimentation chamber for a surface sand filter shall be sized to at least 25% of the computed WQ_v and have a length-to-width ratio of 2:1. **Equation 3** (the Camp-Hazen equation) is used to compute the required surface area. For perimeter sand filters, the sedimentation chamber shall be sized to at least 50% of the computed WQv and the same approach as for surface sand filter shall be used.

Equation 3. Sedimentation Chamber Area

$$A_s = -(Q_o/w) * Ln\,(1-E)$$

Where:

- A_s = sedimentation basin surface area (ft2)
- Q_o = rate of outflow = the WQ_v over a 24-hour period (ft^3/s)
- w = particle settling velocity (ft./sec)
- E = trap efficiency

Assuming:
90% sediment trap efficiency (0.9)
particle settling velocity (ft/sec) = 0.0033 ft/sec for imperviousness ≥75%
particle settling velocity (ft/sec) = 0.0004 ft/sec for imperviousness < 75%
average of 24 hour holding period

Then:
A_s = (0.066) (WQ_v) ft2 for I < 75%
A_s = (0.0081) (WQ_v) ft2 for I ≥75%

Compute storage volumes within entire facility and sedimentation chamber orifice size.

Surface sand filter:

Equation 4a. Surface Sand Filter

$$V_{min} = 0.75\ WQ_v = V_s + V_f + V_{f\text{-}temp}$$

Compute V_f = water volume within filter bed/gravel/pipe = $A_f * d_f * n$
Where: n = porosity = 0.4 for most applications

Compute $V_{f\text{-temp}}$ = temporary storage volume above the filter bed = $2 * h_f * A_f$.

Compute V_s = volume within sediment chamber = V_{min} - V_f - $V_{f\text{-temp}}$.

Compute h_s = height in sedimentation chamber = V_s/A_s.

Ensure h_s and h_f fit available head and other dimensions still fit - change as necessary in design iterations until all site dimensions fit.

Size orifice from sediment chamber to filter chamber to release Vs within 24-hours at average release rate with 0.5 hs as average head.

Design outlet structure with perforations allowing for a safety factor of 10 .

Size distribution chamber to spread flow over filtration media - level spreader weir or orifices.

Perimeter sand filter:

Equation 4b. Perimeter Sand Filter

$$V_f = \text{water volume within filter bed/gravel/pipe} = A_f * d_f * n$$

Where: n = porosity = 0.4 for most applications
Compute V_w = wet pool storage volume A_s * 2 feet minimum.

Compute V_{temp} = temporary storage volume = V_{min} - ($V_f + V_w$).

Compute h_{temp} = temporary storage height = V_{temp} / ($A_f + A_s$).

Ensure h_{temp} ≥2 * h_f, otherwise decrease h_f and re-compute. Ensure dimensions fit available head and area change as necessary in design iterations until all site dimensions fit.

Size distribution slots from sediment chamber to filter chamber.

Pre-Treatment Forebay

Pre-treatment is integral to maintaining the longevity of a sand filter. A forebay shall be located at each major inlet to trap sediment and preserve the capacity of the sand filter. Other forms of pre-treatment for sheet flow and concentrated flow for minor inflow points shall be designed consistent with pre-treatment criteria found in Chapter 6, Section 3. The following criteria apply to forebay design:

- The forebay consists of a separate cell, formed by an acceptable barrier. (e.g., an earthen berm, concrete weir, gabion baskets, etc.).
- The bottom of the forebay may be hardened (e.g., concrete, asphalt, or grouted riprap) in order to make sediment removal easier.
- Surface sand filters require a sediment forebay and perimeter sand filters require a sedimentation chamber.
- Sites with less than 50% imperviousness or high clay/silt sediment loads shall not use a sand filter without adequate pre-treatment due to potential clogging and failure of the filter bed. Any disturbed areas within the sand filter facility drainage area shall be identified and stabilized. Filtration controls shall only be constructed after the construction site is stabilized.

Emergency Spillways, Inlets, and Outlets

Sand filters shall be constructed with overflow capacity to pass the 100-year design storm event through either the Primary Spillway or a vegetated or armored Emergency Spillway. The following criteria apply to spillway design:

- For a surface sand filter, size the overflow weir at elevation h_s in sedimentation chamber (above perforated stand pipe) to handle surcharge of flow through filter system from 25-year storm.
- Plan inlet protection for overflow from sedimentation chamber and size overflow weir at elevation h_f in filtration chamber (above perforated stand pipe) to handle surcharge of flow through filter system from 25-year storm.
- For a perimeter sand filter, size overflow weir at end of sedimentation chamber to handle excess inflow, set at WQ_v elevation.

6.18.4: Construction, Protection, and Maintenance Requirements

All BMPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all BMPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For City policies, additional guidance, and forms pertaining to BMP protection, inspection, and maintenance requirements, see Appendix B of this manual.

Requirements DURING Construction

- Simple erosion and sediment control measures, such as temporary stabilization, silt fencing, and inlet protection, shall be used in areas of the site that drain to the sand filter.
- Appropriate containment shall be used for material storage to prevent accidental discharge to the sand filter.
- Areas where BMPs will be located shall be readily identifiable and protected from unwanted encroachments during construction, both on development plans and at the construction site. Physical protection measures can include, but are not limited to, orange fencing, wood or chain link fencing, and signage.

- Divert flows temporarily from seeded areas until stabilized.
- Areas with heavy flows shall be stabilized with erosion control mats or sod.
- Pavement shall be established over the contributing pervious drainage areas before storm water can be accepted into the sand filter. This will prevent sediment from accumulating in the basin.

Protection Requirements

- Provide signage for the BMP.
    - Allows for easy identification and location of the BMP.
    - Serves as a general education tool, making those responsible for property, landscape or BMP maintenance, and the general public aware of the water quality features of the BMP and to avoid encroachment.
- Design the layout of the sand filter such that maintenance access can be achieved without the need for vehicles or equipment in the storm water treatment area.

Inspection Requirements

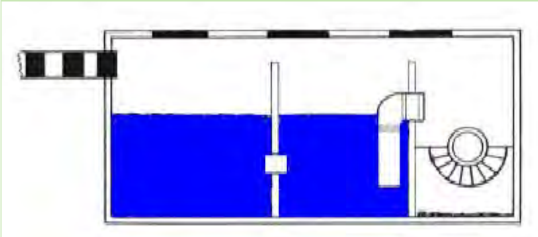
- Inspect for excessive trash, debris, sediment, oil, chemicals, and accumulation at inflow points.
- Inspect for ponding that may signify clogging at inflow points.
- Inspect for damaged or cracked components.
- Rake top inch of filter media and inspect for signs of clogging.

Maintenance Requirements

- Replace media as necessary.
- Remove track and debris build-up.
- Repair or replace damaged components.

6.19 Gravity (oil-grit) Separator

Figure 6.19.1: Gravity (oil-grit) Separator



DEVELOPMENT ATTRIBUTES

Construction Cost	LOW
Operation and Maintenance Cost	HIGH
Ground-Level Encroachment	LOW
Building Footprint Enhancement	LOW
Triple Bottom-Line Benefits	LOW

Description:

An oil-grit separator is a device designed to remove suspended solids, oil, grease, debris, and floatables from storm water through gravitational settling, hydrodynamic separation, and trapping of pollutants. Oil-grit separators are also called gravity separators or oil-water separators.

Key Advantages:

- Well-suited for use on urban development sites, where larger or above-ground BMPs are not an option, or for storm waterretrofit projects
- Can be used as pretreatment for other BMPs
- Can replace a conventional junction or inlet structure
- Multiple inlets can connect to a single unit
- Some designs require minimal drop between inlet and outlet

Key Limitations:

- Dissolved pollutants are not effectively removed by oil-grit separators
- Oil-grit separators alone cannot achieve the 80% TSS removal target
- Frequent maintenance is required
- Performance is dependent on design and frequency of inspection and cleanout of unit
- Some designs may require a confined space entry for inspection, maintenance, and repairs

PERFORMANCE STANDARD COMPLIANCE					
Water Quality			Stream Channel Protection	Overbank Flood Protection	Extreme Flood Protection
Treatment Volume		80% TSS Removal			
Level 1	Level 2				
Not Approved	Not Approved	▶			

✓ Suitable for this practice

▶ Provides partial benefits

6.19.1 General Application

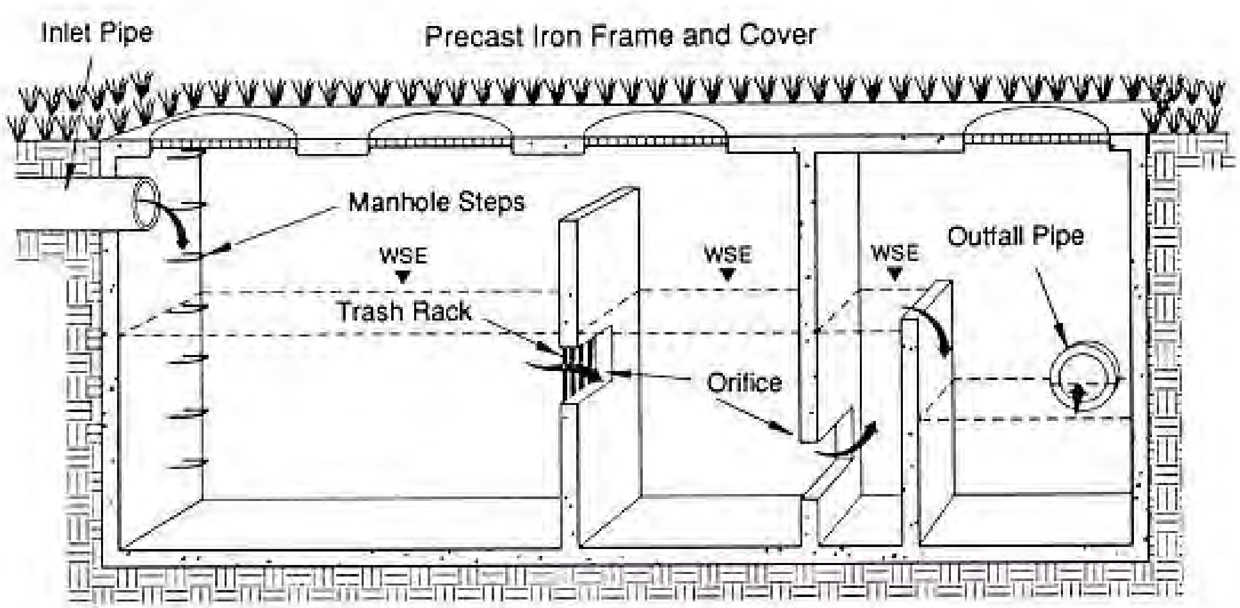
Gravity oil-grit separators are hydrodynamic separation devices that are designed to remove grit, heavy sediments, oil, grease, debris, and floatable matter from storm water through gravitational settling and trapping. Gravity separator units contain a permanent pool of water and typically consist of an inlet chamber, separation and storage chamber, a bypass chamber, and an access port for maintenance purposes (see **Figure 6.19.2**). Runoff enters the inlet chamber where heavy sediments and solids drop to the bottom. The flow moves into the main gravity separation chamber, where further settling of suspended solids takes place. Oil and grease are skimmed and stored in a waste oil storage compartment for future removal. After moving into the outlet chamber, the clarified storm water is then discharged.

The performance of these systems is based primarily on the relatively low solubility of petroleum products in water and the difference between their specific gravities. Gravity separators are not designed to separate other products, such as solvents, detergents, or dissolved pollutants. The typical gravity separator unit may be enhanced with a pretreatment swirl concentrator chamber, oil draw-off devices that continuously remove the accumulated light liquids, and flow control valves regulating the flow rate through the facility.

Gravity separators are often used in commercial, industrial, and transportation land uses and are intended primarily as a pre-treatment measure for high-density or ultra-urban sites or for use in hydrocarbon hotspots, such as gas stations and areas with high vehicular traffic. However, gravity separators cannot be used for the removal of dissolved or emulsified oils and pollutants such as coolants, soluble lubricants, glycols, and alcohols.

Since resuspension of accumulated sediments is possible during heavy storm events, gravity separator units shall be installed off-line. Gravity separators are available as prefabricated proprietary systems from a number of different commercial vendors.

Figure 6.19.2. Gravity (oil-grit) Schematic



6.19.2 Planning and Physical Feasibility

The following feasibility issues need to be evaluated when gravity separators are considered. The following criteria provided in **Table 6.19.1** shall be considered when evaluating the suitability of a gravity separator for a development site.

Table 6.19.1. Gravity Separator Constraints

Contributing Drainage Area	Hotspot Land Uses	Hydraulic Head needed	Site Layout
5 acres max. 1 acre max. impervious cover	No constraints, well-suited for hot spot runoff.	Minimum head shall be 4 feet and the minimum depth of the permanent pools shall be 4 feet.	Not allowed in areas where operation may create a risk for basement flooding, interfere with subsurface sewage disposal systems, or affect other underground structures. Overflow shall drain away from buildings to prevent damage to foundations.
Manufacturer Recommendations	Site Slope	Space Required	Water Table Requirement
Check with manufacturer recommendations for additional site design constraints.	<6%. A minimum 20 foot wide maintenance right-of-way or drainage easement shall be provided and shall have a max. slope <15%.	Total wet storage shall be at least 400 cubic feet per contributing impervious acre. Gravity oil-grit separators are installed underground; therefore, minimal surface area is required.	2 ft. of separation

The data listed below is necessary for the design of a sand filter and shall be included with the development plan. See Appendix B for more information on required elements for the development plan.

- Existing and proposed site, topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Water surface elevation of nearby water systems as well as the depth to seasonally high groundwater.
- Infiltration testing of native soils at proposed elevation of bottom of sand filter.

6.19.3 Design Requirements

Another BMP or GIP shall be used in a treatment train with gravity separators to provide runoff reduction as they are not designed to provide RR_V as a stand-alone BMP.

The following design specifications are required:

- The design criteria and specifications of a proprietary gravity separator unit shall be obtained from the manufacturer.
- The separation chamber shall provide for three separate storage volumes:
    - A volume for separated oil storage at the top of the chamber.
    - A volume for settled solids accumulation at the bottom of the chamber.
    - A volume required to give adequate flow-through detention time for separation of oil and sediment from the storm water flow.

- Gravity separator units are typically designed to bypass runoff flows in excess of the design flow rate. Some designs have built-in high flow bypass mechanisms. Other designs require a diversion structure or flow splitter ahead of the device in the drainage system. An adequate outfall shall be provided.
- A trash rack shall be included in the design to capture floating debris, preferably near the inlet chamber to prevent debris from becoming oil impregnated.
- An oil draw-off mechanism shall be included that empties to a separate chamber or storage area.
- Gravity separator units shall be watertight to prevent possible groundwater contamination.

Storm Water Quality

Refer to manufacturer instructions and tools to design the gravity oil-grit separator based on the appropriate design flow rate and volumes.

Safety Features

The deep inverts, open void sections, and sometimes larger pipe diameters into and out of oil-grit separators may present a fall or entrapment hazard. Gravity oil-grit separators shall be constructed with manhole covers and/or grate lids with locking mechanisms. Structural loading calculations, such as H-20 loading for traffic areas, shall be performed when sizing and installing gravity oil-grit separators. Some oil-grit separators are considered confined spaces. Additional training may be required to perform work inside the units.

Inlets

Gravity oil-grit separators are typically used for pretreatment in a hotspot area or where floatable debris and pollutants are to be removed prior to additional treatment. Inlets sizing, slope, and invert placement shall be sized based on manufacturer's recommendations for flow rate, volume, and structure size.

Outlets

An important consideration when designing an oil-grit separator system for a site is how to bypass large storm events that exceed the design flow capacity around the separator without damaging the unit, exceeding the design flow capacity, or re-suspending collected pollutants. Since resuspension of accumulated sediments and oil droplets is possible during heavy storm events, oil-grit separator units shall be installed off-line with a bypass to minimize pollutant wash-out or resuspension in these instances.

The outlet from the gravity separator shall convey storm water leaving the gravity separator as well as the bypassed discharge without eroding the surrounding area. Typically, the high flow outlet will discharge at a higher elevation than the low flow outlet. All overflow pipes shall be directed away from buildings to prevent damage to building foundations.

Use manufacturer-recommended design methods to determine the size, slope, and invert of the device outlet.

Ensure downstream receiving BMPs and/or storm drain systems can receive the volume and rate of storm water flow from the gravity oil-grit separator and/or bypass system.

A hydraulic grade analysis shall be performed to ensure that the receiving storm water system can accept the flow, and that the oil-grit separator does not create a hydraulic head jump that exceeds the elevation of the upstream system.

6.19.4 Construction, Protection, and Maintenance Requirements

All BMPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all BMPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For City policies, additional guidance, and forms pertaining to BMP protection, inspection, and maintenance requirements, see Appendix B of this manual.

Requirements During Construction

- Contributing drainage areas to the gravity oil-grit separator shall be stabilized with appropriate erosion and sediment control devices, such as with temporary or permanent seeding before runoff can enter a newly installed-device.
- Newly installed gravity oil-grit separators shall be inspected prior to being placed in service. Remove sediment and debris that may have been collected during delivery and installation.
- A minimum 20-foot wide maintenance right-of-way or drainage easement shall be provided for the oil-grit separator from any public or private road or driveway.

Protection Requirements

- Provide signage for the BMP.
    - Allows for easy identification and location of the BMP.
    - Serves as a general education tool, making those responsible for property, landscape or BMP maintenance, and the general public aware of the water quality features of the BMP and to avoid encroachment.
- Design the layout of the sand filter such that maintenance access can be achieved without the need for vehicles or equipment in the storm water treatment area.

Inspection Requirements

- Inspect to make sure access to the site is adequate for inspection and maintenance.
- Inspect to make sure area is clean (trash, debris, grass clippings, weeds etc. removed).
- Inspect to make sure inlet and outlet pipes are free of trash, debris, etc. Inspect for ponding that may signify clogging at inflow points.

Maintenance Requirements

- Remove trash and other pollutants from the BMP and surrounding area.
- Follow manufacturer's instructions for proper removal and disposal of oil, sediment, and solids.

6.20 Manufactured Treatment Device

Mechanical Filtration

80% TSS Removal

Figure 6.20.1: Maintenance of a Manufactured Treatment Device

DEVELOPMENT ATTRIBUTES

Construction Cost	MODERATE
Operation and Maintenance Cost	HIGH
Ground-Level Encroachment	LOW
Building Footprint Enhancement	LOW
Triple Bottom-Line Benefits	LOW

Description:

Manufactured treatment devices (MTDs) are storm water BMPs and treatment systems available from commercial vendors. MTDs are sometimes referred to as proprietary BMPs. MTDs are designed to treat storm water and provide water quantity control. There are many types of MTDs available on the market, including:

- Hydrodynamic systems, such as gravity and vortex separators
- Filtration systems
- Catch basin media inserts
- Chemical treatment systems
- Package treatment plants
- Prefabricated detention structures

MTDs are stormwater practices which primarily rely on "flow-through" technology to remove pollutants. That is, stormwater flows through the device without significant detention time, and pollutants are removed using some internal technology which separates, filters, baffles or otherwise manages the inflow. In general, MTDs will not provide runoff reduction, but are most appropriate for TSS removal.

Key Advantages:

- MTDs can be chosen or designed for a site's specific storm water runoff characteristics and/or design constraints.
- Often, MTDs are well-suited for use on urban development sites where larger or above-ground GIPs are not an option or for storm water retrofit projects.
- Can be used as pretreatment for GIPs.
- Can replace a conventional junction or inlet structure.
- Some designs require minimal drop between inlet and outlet.

Key Limitations:

- Dissolved pollutants may not be effectively removed
- May not achieve the 80% TSS removal target alone
- Performance dependent on design and maintenance of individual units

PERFORMANCE STANDARD COMPLIANCE					
Water Quality			Stream Channel Protection	Overbank Flood Protection	Extreme Flood Protection
Treatment Volume		80% TSS Removal			
Level 1	Level 2				
Not Approved	Not Approved	✓			

✓ Suitable for this practice

▶ Provides partial benefits

6.20.1 General Application

MTDs are useful on small sites and space-limited areas where there is not enough land or room for other storm water treatment alternatives. MTDs can be also used as pretreatment in a treatment train. However, MTDs can sometimes be an undesirable option for a property owner. MTDs can be more costly than other alternatives when cost is examined over the life of a BMP. This is due to their high inspection and maintenance requirements. **Therefore, MTDs used should be limited to properties where GIPs and other BMPs are not feasible, and the future owner can reasonably manage the MTDs' inspection and maintenance requirements and associated costs.**

One of the difficulties in allowing MTDs as an acceptable storm water quality practice is the lack of adequate independent performance data, particularly for use in local conditions. As local governments are being asked to review and approve emerging storm water treatment technologies, a consistent testing protocol and a process for evaluating and accepting MTDs is necessary. The objective of this section is to provide site designers with a starting point for evaluating a particular MTD's effectiveness in removing pollutants from storm water runoff for an intended application and to compare test results with vendor performance claims.

This section is not intended to set testing protocols or procedures for evaluating the performance of a MTDs. Furthermore, the lack of consistent review and evaluation of monitoring and performance data has been a source of frustration for local governments, vendors, and the development community.

The City of Birmingham will only accept MTDs that meet the Metropolitan North Georgia Water Planning District's Post-Construction Stormwater Technology Assessment Protocol (PCSTAP). A list of the accepted BMPs can be found at www.northgeorgia.org under "Proprietary Technology Assessment Protocol". The PCSTAP provides the City with a way to ensure that MTDs installed under local water quality requirements have a demonstrated ability to meet the storm water management goals and uses for which it is intended. According to PCSTAP, this means that the device has:

1. Independent third-party scientific verification of the ability of the MTD to meet water quality treatment objectives and/or to provide water quantity control (channel or flood protection);
2. A proven record of longevity in the field; and
3. Proven ability to function in local conditions (e.g., climate, rainfall patterns, soil types).

More information on the PCSTAP can be found at www.northgeorgia.org.

6.20.2 Planning and Physical Feasibility

MTDs are very compact and are often found to be especially useful for total suspended solids (TSS) Removal at small sites and space-limited areas where there is not enough land or room for GIPs. They can also be used for TSS pretreatment in a treatment train upstream of GIPs. Some MTDs are especially well-suited for storm water quality management on hotspots or for debris removal. However, when considering life-cycle costs, MTDs may prove costlier than GIPs because of their need for frequent inspection and routine maintenance. The following criteria provided in **Table 6.20.1** shall be considered when evaluating the suitability of an MTD for a development site.

Table 6.20.1. MTD Constraints

Manufacturer Recommendations	Storm Water Flow	Subject to Approval and Verification
Drainage area, slope, soils, flow velocity, storage area, permanent pool depth, inlet/outlet considerations, and other design criteria shall meet the manufacturer's requirements.	Typically designed as "off-line" systems or part of a treatment train.	Demonstrated ability to meet the storm water management goals and uses is required.

The data listed below is necessary for the design of an MTD and shall be included with the development plan. See Appendix B for more information on required elements for the development plan.

- Existing and proposed site, topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Approval and verification information.

6.20.3 Design Requirements

The major design goal for MTDs is to maximize % TSS removal. Generally, runoff reduction is not a control method that MTDs will provide. The commercial vendor providing the MTD will assist the site designer with sizing the MTD for the specific situation for which it is proposed. All design information for MTDs shall be provided in the storm water management plan for the proposed land development. Such information shall include the % TSS removal value used for the storm water quality protection standard compliance calculation.

6.20.4 Construction, Protection, and Maintenance Requirements

All BMPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all BMPs includes considerations for maintenance and maintenance access. MTDs must be included in the maintenance agreement required by the City. For City policies, additional guidance, and forms pertaining to BMP protection, inspection, and maintenance requirements, see Appendix B of this manual.

Requirements DURING Construction

- Simple erosion and sediment control measures, such as temporary stabilization, silt fencing, and inlet protection, shall be used in areas of the site that drain to the MTD.
- Appropriate containment shall be used for material storage to prevent accidental discharge to the MTD.
- Areas where BMPs will be located shall be readily identifiable and protected from unwanted encroachments during construction, both on development plans and at the construction site. Physical protection measures can include, but are not limited to, orange fencing, wood or chain link fencing, and signage.

Protection Requirements

- Provide signage for the MTD if required by the City.
    - Allows for easy identification and location of the BMP.
    - Serves as a general education tool, making those responsible for property, landscape, or BMP maintenance and the general public aware of the water quality features of the BMP and to avoid encroachment.

Inspection Requirements

- Inspect for excessive trash, debris, sediment, oil, chemicals, and accumulation at inflow points
- Inspect for ponding that may signify clogging at inflow points
- Inspect for damaged or cracked components
- Follow the City's MTD inspection requirements

Appendix A

Acronyms and Definitions

Acronyms

The following acronyms are used in this manual.

ACES	Alabama Cooperative Extension System
ADEM	Alabama Department of Environmental Protection
BMP	Best Management Practice
CIP	Capital Improvement Project
CWA	Clean Water Act
CLOMR	Conditional Letter of Map Revision
CN	Curve Number
CRS	Community Rating System
CWA	Clean Water Act
ED	Extended Detention
EDv	Small Storm Extended Detention Volume
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
GIP	Green Infrastructure Practice
IDF	Intensity-Duration-Frequency
LEED	Leadership in Energy and Environmental Design
LID	Low Impact Development
LOMR	Letter of Map Revision
MS4	Municipal Separate Storm Sewer System
NFIP	National Flood Insurance Protection
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resource Conservation Service
Rv	Annual Runoff Reduction Coefficient
SCS	Soil Conservation Service
TMDL	Total Maximum Daily Load
TR-55	Technical Release 55
TSS	Total Suspended Solids
Tv	Treatment Volume
USC	United States Code
USEPA	United States Environmental Protection Agency
USFWS	United States Fish & Wildlife Service
USGS	United States Geological Service

Definitions

Definitions relevant to the policies defined in this manual are provided below. Where this manual and the Storm Water Ordinance conflict, the *City of Birmingham Post Construction Storm Water Ordinance* shall prevail.

Applicable development (or **development**). Developments and redevelopments that are required by the *City of Birmingham Post Construction Storm Water Ordinance* to meet the storm water quality protection standard.

Applicant. Any person, firm, corporation, entity or governmental agency who is the owner or authorized agent of owner of land on which land-disturbing activity is proposed and who submits the necessary design information and forms as the responsible party to procure a post-construction storm water permit.

Best Management Practice (**BMP**). A structural storm water management facility or device that controls storm water runoff and changes the characteristics of that runoff, including, but not limited to, quantity, quality, and period of release or the velocity of flow.

Buffer. Vegetated area near a stream, usually forested, which helps protect the stream from the impact of adjacent land uses. Also called a stream buffer or riparian buffer.

City. The City of Birmingham, Alabama, a municipal corporation organized under the laws of the State of Alabama.

Department. The Department of Planning, Engineering & Permits for the City of Birmingham, Alabama.

Director. The Director of the Department of Planning, Engineering & Permits or his/her authorized representative.

Green Infrastructure Practice (**GIP**). Systems and practices that use or mimic natural processes to infiltrate, evapotranspirate (the return of water to the atmosphere either through evaporation or by plants), or reuse storm water or runoff on the site where it is generated.

Impervious surface (or **impervious cover**). And land cover material that impedes or prevents the natural infiltration of water into the soil. Examples of impervious surfaces include roofs, streets, driveways, parking areas, patios, sidewalks, tennis courts, solid decks, and other concrete or asphalt paved areas. Areas covered by paver blocks, gravel, "crusher stone', or other material and used as vehicle driveways, travel ways, or parking are also considered impervious cover unless the cover will be specifically designed and constructed to allow infiltration of storm water.

Infill Development. New development that is sited on vacant or undeveloped land within an existing community and is fully or partially enclosed by adjacent parcels that are already developed.

Land Disturbance Activities. Any land change which may result in soil erosion from water or wind and the movement of sediment, including, but not limited to, the clearing, dredging, grading, compaction, excavating, transporting, and filling of land.

Low Impact Development (**LID**). An approach to land development (or redevelopment) that works with nature to manage storm water as close to its source as possible. LID employs principles such as preserving and recreating natural landscape features and/or minimizing effective imperviousness to create functional and appealing site drainage that treat storm water as a resource rather than a waste product.

Maintenance Manual. The City of Birmingham Property Owner's Guide to BMP Maintenance.

Manual. The City of Birmingham Post Construction Storm Water Design Manual.

Municipal Separate Storm Sewer System (MS4). A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains): (i) owned or operated by a state, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to state law) having jurisdiction over disposal of sewage, industrial wastes, storm water, or other wastes, including special districts under state law such as a sewer district, flood control district or drainage district, or similar entity, or a designated and approved management agency under section 208 of the Clean Water Act that discharges to waters of the United States; (ii) designed or used for collecting or conveying storm water; (iii) which is not a combined sewer; and (iv) which is not part of a Publicly Owned Treatment Works (POTW) as defined in ADEM Administrative Code335-6-6-.02(nn).

National Pollutant Discharge Elimination System (NPDES). A permit issued by EPA (or by a state under authority delegated pursuant to 33 USC § 1342(b)) that authorizes the discharge of pollutants to waters of the United States and waters of the state, whether the permit is applicable on an individual, group, or general area-wide basis.

New Development. Any tract, lot, or parcel of land, or combination of contiguous tracts, lots, or parcels of land which are in one ownership, or which are owned by two or more parties, and for which improvements of the land from a natural, entirely unimproved, condition are proposed or planned as a unit, subdivision, or project. New development includes land that has been used previously for livestock or crops, or has been previously grubbed, stripped, graded, and/or revegetated from a natural, entirely unimproved condition, provided that impervious surfaces were not previously placed or demolished thereon.

On-site storm water system. The feature or system of features on a land development that are designed and constructed to convey, store, detain, remove, treat, or otherwise manage storm water. The onsite storm water system includes, but is not limited to, catch basins, curbs, gutters, man-made channels, storm drains, inlets, outlets, outfalls, pipes, swales, ditches, channels, culverts, sediment forebays, GIPs, BMPs, manufactured treatment devices, and appurtenances related to all of the above.

Ordinance. The City of Birmingham Post Construction Storm Water Ordinance.

Performance Standard. The benchmark against which the design of the storm water drainage system, or a specific component of the system, is measured. A design must meet the performance standard for it to be deemed compliant.

Pervious surface. Any land cover that does not fit the definition of impervious surface provided above. Examples of pervious surfaces include forests and wooded areas, meadow, grass, plant beds, areas of bare soil, areas of erosion, and permeable pavement (e.g., asphalt, concrete) and paver block areas that are (or will be) designed to infiltrate storm water (with or without an underdrain) are also pervious areas.

Pre-Construction Condition. The existing condition of the property at the time the application for a Post Construction Storm Water Permit is submitted, prior to any clearing, grubbing, grading, construction, or demolition done in preparation for the proposed new development or redevelopment. For new land developments, the pre-construction condition will be an undeveloped condition. For redevelopments, the pre-construction condition will be a developed condition. If demolition of pavement or structures has already occurred in preparation for the proposed redevelopment when the application for a Post Construction Storm Water Permit is received, the pre-construction condition shall be the previously developed condition of the property, as obtained from aerial photography, historical mapping, or other reliable source of land cover information.

Pollutant. Anything which causes or contributes to pollution. Pollutants may include, but are not limited to, dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, or industrial, municipal, and agricultural waste discharged into water. The term also includes any other effluent characteristics specified in the City's NPDES permit.

Redevelopment. The expansion, renovation, rebuilding, demolition and construction, or other further improvement of any previously improved tract, lot, or parcel of land, or combination of contiguous tracts, lots, or parcels of land which are in one ownership, or which are owned by two or more parties, are proposed or planned as a unit, subdivision, or project. "Previously improved" includes, but is not limited to, the prior placement, construction, and/or demolition of buildings, roadways, sidewalks, parking areas, and other areas of concrete, asphalt, gravel, packed gravel, or other materials on the subject tract(s), lot(s) or parcel(s).

State. The State of Alabama.

Storage practice (also storage BMP). A structural facility designed and constructed to provide storage of storm water for flood control. Detention ponds and retention ponds are examples of storage practices.

TSS Removal BMP. A structural storm water management facility or device that is designed and constructed to remove pollutants from storm water runoff, particularly TSS.

Appendix B
Plan Submittal Checklists and Related Forms

City of Birmingham, Alabama

Post Construction Storm Water Pre-Concept Sketch Checklist

Shaded areas are to be completed by the City of Birmingham ONLY.			
Permit Number:	____	**Case No:**	____________
Date Received:	____		

Property Address: ____

Directions: Desired items for the pre-concept sketch are listed below. Much of this data should be readily available from topographic maps, aerials, photographs, etc. Provide as much information as possible. Items that are not readily available are not required. Indicate whether or not the item/information is included by placing an X in the Yes, No or NA (not applicable) boxes.

Yes	No	NA	Item Description and/or Information	City Staff Notes
			General Information	
			1. Name and contact information of developer	
			2. Common address and legal description of site	
			3. Name and contact information of report preparer	
			4. Vicinity map sufficient information as necessary to accurately locate the property (e.g., adjacent roadways, property lines, parcel ID, etc.)	
			5. Narrative describing the potential development project, including the current and proposed future zoning designation (narrative space provided at end of checklist)	
			6. Other ____	
			Existing Condition Hydrologic Characterization Maps / Data (Please create all maps to the same scale if possible)	
			1. Topography (USGS quadrangles accepted, 2-foot contour intervals preferred)	
			2. Drainage basin boundaries (and watershed name(s) if known)	
			3. General land cover areas, using the land cover categories below: • Undisturbed forest, indicate good, fair, or poor condition • Undisturbed non-forest vegetation, indicate predominate vegetation and condition (e.g., native shrubbery - good condition) • Managed turf or other managed landscaping • Bare soil • Impervious (rooftop, pavement, gravel, etc.)	
			4. Streams, regulatory floodplains, regulated/designated stream buffers, wetlands, sinkholes, seeps, springs and slopes greater than 15%	
			5. Delineate Hydrologic Soil Groups A, B, C and D, in undeveloped areas only. In previously developed areas, delineate the boundaries of farmed (crop) soils and urban (fill or compacted) soil.	
			6. Areas of known or suspected pollutants in the soil (surface or subsurface)	
			7. Areas of shallow bedrock, high water table, hardpan, clay lenses and other similar subsurface conditions, if known	
			8. Water supply basins, groundwater recharge areas and wellhead protection areas	
			9. Existing conservation areas	
			10. Areas where wet conditions or flooding is known to have occurred	
			11. Existing utility corridors	
			12. Areas with geotechnical or structural concerns, contractive/expansive soils, etc.	
			13. Areas of cultural, historical, archeological or wildlife significance	
			14. Any other relevant data/test results, such as soil borings and other geotechnical data, soil analyses, capacity studies, etc.	
			15. Other ____	

Post Construction Storm Water Pre-Concept Sketch Checklist continued

Narrative:

City of Birmingham, Alabama

Infiltration Feasibility Form

Shaded areas are to be completed by the City of Birmingham ONLY.			
Plan Name:	______________________________		
Date Received:	______________________________	**Case No.:**	______________

Property Address: ____

GIP ID _________ **GIP location on the property** ______________________________________

This form must be completed for proposed new developments and redevelopments for which a Post Construction Storm Water Permit is required and include one or more infiltration-based GIPs that are designed without an underdrain (e.g., bioretention areas, infiltration trenches). One form must be completed for each infiltration-based GIP without an underdrain proposed. The completed and signed form must be provided with the Storm Water Management Plan.

All conditions listed below must be met for approval of any infiltration-based GIP without an underdrain. Failure to meet every condition indicates the infiltration-based GIP without an underdrain is not feasible. Either the GIP must be relocated and/or redesigned or a different GIP or BMP must be selected. Consult the *City of Birmingham Post Construction Storm Water Design Manual* for more information on the selection and application of GIPs and BMPs.

Indicate with a check (✓) the conditions that are (or will be) true for the subject GIP. If additional explanation is needed, please provide on the back of this form.

SOILS

- ☐ The GIP is located in native A or B soils
- ☐ Infiltration tests at the GIP location indicate an infiltration rate of 0.5"/hour or more *(see Appendix E for infiltration test guidance)*

HOT SPOT

- ☐ No hot spots are present *(see Appendix D for hot spot definition)*

GROUNDWATER TABLE AND BEDROCK

- ☐ At least 2-feet of vertical separation is provided between the bottom elevation of the GIP and the seasonal groundwater table
- ☐ At least 2-feet of vertical separation is provided between the bottom elevation of the GIP and the bedrock

KARST

- ☐ No sinkholes or karst features are present at or near the GIP location *(see Appendix D for more information)*

WATER SUPPLY WELLS

- ☐ The GIP is located at least 100 ft from water supply wells, well head protection areas, and groundwater protection areas

SETBACKS FOR STRUCTURES

- ☐ The GIP is located at least 25 ft downgradient from all structures

MAXIMUM DRAINAGE AREA

- ☐ The drainage area for the GIP is 2.5 acres or less

Signature of Licensed Individual ____

License No. ______________________________ **Date**__________________________________

Notes:____

City of Birmingham, Alabama

Post Construction Storm Water
Storm Water Management Plan (SWMP) Checklist

Shaded areas are to be completed by the City of Birmingham ONLY.			
Reviewer:	**____**	**Case No.:**	**____________**
Date Received:	**____________________________**	**Date Approved:**	**__________________________**

Property Owner: ____

Property Address: ____

SWMP Preparer: ____

Contact Information: ____

Directions: Indicate if the item/information is included by placing an X in the Yes, No, or NA boxes. Provide a response for each item.
Yes = Item included. No = Item not available or not included. NA = Not applicable.

(Maps shall be provided at a scale commensurate with construction drawings, and no less than 1" = 50', except where noted below.)

Yes	No	NA	Item Description and/or Information	City Staff Notes
			General Information	
			1. Applicant information (name, legal address, and telephone number)	
			2. Common address and legal description of site	
			3. Date(s) of report preparation and any revision(s)	
			4. Name and contact information of responsible designer	
			5. Signature and stamp of registered engineer and landscape architect	
			6. Executed maintenance agreement with a map showing property boundaries, address, cross-streets and bounding roadways with names, structures and pavement that will exist onsite after proposed development is complete, and the location and type of all GIPs and BMPs that will be located onsite after the proposed development is complete.	
			7. Vicinity map including:	
			a. North arrow	
			b. Scale	
			c. Adjacent roadways	
			d. Other information as necessary to locate the development site	
			8. Narrative describing the proposed project, better site design and techniques, intrinsic GIPs used, LID practices used, and any structural GIPs and BMPs used for storm water quality, stream erosion, overbank flood and extreme flood protection	
			9. Topography, provided at 2-foot contour intervals with 1-foot accuracy. One-foot contours are preferred where available	
			10. Drainage basin boundaries [and watershed name(s) if known]	
			<u>EXISTING CONDITION</u> Pre-Concept Sketch	
			1. Land cover area map, using the land cover categories: - Forest - Urban Forest - Meadow/Turf - Impervious Cover (identify total area [in acres and square feet] and type: building, pavement, gravel, etc.)	

Post Construction Storm Water Management Plan Checklist continued

Yes	No	NA	Item Description and/or Information	City Staff Notes
			2. Streams, regulatory floodplains, regulated/designated stream buffers, wetlands, karst/sinkhole areas, seeps, springs and slopes greater than 15%	
			3. Areas of known or suspected pollutants (surface or subsurface)	
			4. Water supply basins, groundwater recharge areas, and wellhead protection areas	
			5. Existing conservation areas	
			6. Areas where wet conditions or flooding are known to have occurred	
			7. Areas of cultural, historical or archeological significance	
			8. Areas with threatened and endangered species, if known	
			9. Soils information (refer to Appendix E), including: - Soil survey Information - Map and designation of hydrologic soil groups and urban soils - Subsurface conditions (if available) - On-site soil evaluation (if available) - Infiltration test results (if available) - Other available geotechnical information	
			10. Other____	
			11. Other____	
			Hydrologic & Hydraulic Analyses & Compliance Report *(analyses shall include the following for on-site sub-basins and appropriate off-site areas)*	
			1. Record of Storm Water Pre-Concept Process Meeting	
			2. Maps and narrative describing whether and how the ***storm water quality performance standard*** is achieved at the site (i.e., compliance with the Rv criterion and/or the 80% TSS removal criterion), including identification of qualifying limitations, incentives applied, and GIPs/BMPs used	
			3. Statement by the engineer of record relative to the impact of the proposed storm water drainage system on the existing storm sewer system. See Appendix B.	
			4. Proposed condition for all storm water management BMPs and GIP types and locations, including a map showing contributing drainage area to each GIP/BMP	
			5. Proposed condition storm water quality volumes and associated performance standard compliance data (Rv or % TSS Removal) for the development conditions, including all supporting data and calculations	
			6. Map(s) and associate narratives that indicate the measures used to protect storm water quality GIPs after their installation to ensure vegetation survival (if applicable), soil compaction prevention (if applicable), erosion prevention and sediment control within and to the GIP, and structural or environmental damage	
			7. Maps and narratives describing the pre-development and post-development conditions and how the ***small storm ED, overbank and extreme flood protection performance standards*** and the downstream hydrologic analysis criterion are achieved at the site	
			8. Drainage basin map with sub-basins and soil conditions identified	
			9. Name(s) and version(s) of software used for analyses	
			10. Curve numbers or C-Factors, other runoff factors used, infiltration rates, etc.	
			11. Times of concentration for pre- and post-development flow paths, other hydrologic factors and travel time parameters	
			12. Rainfall data used	
			13. Proposed condition stream erosion protection compliance, extended detention of the 1-year storm and design release period, including supporting data and required calculations	
			14. Annual Rv calculations demonstrating $Rv \leq 0.22$ or TSS Removal calculations demonstrating 80% TSS removal (can use report from Birmingham Storm Water Quality Design Tool)	
			15. Proposed condition storm water peak discharges for the 1-year frequency, 24-hour duration storm event for the small storm extended detention design requirement (show method used and supporting calculations)	

Post Construction Storm Water Management Plan Checklist continued

Yes	No	NA	Item Description and/or Information	City Staff Notes
			16. Table comparing the pre- and post-construction conditions for each design storm event (2-, 10- and 25-year, 24-hour return frequency events) (show method used and supporting calculations)	
			17. Confirmation that the 100-year frequency, 24-hour storm event will be discharged safely (show method used and supporting calculations and conclusions)	
			18. Proposed condition hydrologic/hydraulic analyses and final sizing specifications for storm water quantity GIP designs, including all supporting data (contributing drainage area, required storage, outlet configuration, etc.) and calculations	
			19. Design water surface elevations, where applicable	
			20. Stage-discharge or outlet rating curves and inflow-outflow hydrographs for storage facilities	
			21. Results and supporting calculations for the downstream hydrologic analysis criterion, including analysis locations, supporting data and calculations and comparison table of pre-development and post-development peak discharges at all analysis locations	
			22. Existing and proposed structure elevations (e.g., pipe inverts, manholes, etc.)	
			23. Proposed condition storm water velocities in all storm water conveyances, at GIP outlets, and at property outfalls (show methods used and supporting calculations)	
			24. Construction notes, specifications, and design details for any storm water system components	
			25. Map(s) and associate narratives that indicate the measures used to protect GIPs and BMPs after their installation to ensure vegetation survival and prevent structural or environmental damage. If BMPs will be used as pre-treatment areas or sediment basins during construction, indicate the measures used to remove sediment from the basin to restore the design capacity, the general timing of sediment removal within the construction schedule, and the measures used to stabilize the soil within and around GIP after sediment removal (if applicable).	
			26. Other____	
			27. Other____	
			Vegetation Report *(This report is applicable to those BMPs that include vegetation to facilitate runoff reduction, pollutant removal or soil stabilization. Refer to Appendix C. Drawings shall be provided at no greater than 1" = 100').*	
			1. A table that lists the proposed GIPs that include vegetation and required vegetation type(s) and coverage percentage(s). Indicate where proposed vegetation type(s) and coverage percentage(s) will not meet GIP requirements and include rationale for non-compliance. *If no proposed GIPs include vegetation (this is not common), check NA for all GIP Vegetation Report requirements.*	
			2. Individual, proposed condition vegetation map or drawing **for each GIP listed in item 1 immediately above,** indicating: a. Proposed plant density b. Expected vegetation coverage and individual plant spread upon maturity c. Notations providing the vegetation type (e.g., tree, shrub, grass) and indication of native or non-native d. Names of plant species	
			3. Narrative or explanatory table **for each GIP listed in item 1 immediately above**, providing: a. Expected time of vegetation installation b. Measures to be employed to protect the vegetation after installation c. Measures to be employed to ensure the survival of vegetation after its installation and while the property is still under construction, such as watering, fertilization, pest management, etc. *Indicate how often such measures will be needed and where/how water will be obtained.*	

Post Construction Storm Water Management Plan Checklist continued

Yes	No	NA	Item Description and/or Information	City Staff Notes
			4. A map showing all property drainage basins and associated GIPs, showing the proposed land cover within each drainage basin (impervious or pervious) and the expected condition of each land cover (stabilized by paving or permanent vegetation) during and immediately after GIP installation. *(Note that construction sequencing shall be such that storm water **quality** GIPs are installed only after permanent stabilization of the GIP's contributing drainage area.)*	
			5. Other____	
			6. Other____	
			Construction and Protection Report *(This report provides information on preventing soil compaction for infiltration BMPs and providing soil erosion and sediment control.*	
			1. Construction equipment and other encroachments are restricted from GIP infiltration areas	
			2. Plan for soil testing, soil restoration, soil amendments, and/or engineered soil media established	
			3. Any existing or proposed stream crossings or wetland/waterway impacts. Copies of state and/or federal permits allowing the crossing or encroachment, if applicable.	
			4. Description and/or drawings indicating the species and planting of proposed vegetation, in accordance with the vegetation requirements stated in Appendix C	
			5. Descriptions and/or drawings indicating the planting practices that will be utilized	
			6. A maintenance and monitoring plan for one full growing season, including specification of proposed watering plans and schedule	
			7. Other____	
			8. Other____	
			Operation & Maintenance Report	
			1. A map showing property boundaries, address, cross-streets and bounding roadways with names, structures and pavement that will exist onsite after proposed development is complete, and the location and type of all GIPs and BMPs that will be located onsite after the proposed development is complete. This map also must show the locations of all easements. The language used to identify each GIP and BMP in the map must be consistent with the names used in the City of Birmingham Storm Water Design Manual.	
			2. Location and description GIP/BMP protective measures, as applicable	
			3. Description of maintenance requirements for overall storm water functions and for each GIP and BMP, including cleanout, repair, and vegetation replacement, etc.	
			4. Inspection and maintenance checklists for each type of GIP and BMP that is located on the property	
			5. Other____	
			6. Other____	

Notes:

City of Birmingham, Alabama

Post Construction Storm Water Record Drawing Checklist

Shaded areas are to be completed by the City of Birmingham ONLY.

Reviewer: ______________________________________ **Case No.:** ____________

Date Received: ___________________________ **Date Approved:** _________________________

Property Owner: ____

Property Address: ____

Record Drawing Preparer: ____

Contact Information: ____

Directions: Indicate if the item/information is included by placing an X in the Yes, No, or NA boxes. Please provide a response for each item.
Yes = Item included. No = Item not available or not included. NA = Not applicable.

Yes	No	NA	Item Description and/or Information	City Staff Notes
			Certification Requirements	
			1. Signed original of the Post Construction Storm Water Permit Certification and Closure Request	
			2. Signed original of the Post Construction Storm Water Record Drawing Certification for Registered Land Surveyors	
			3. Signed original of the Post Construction Storm Water Record Drawing Certification for Engineers and Landscape Architects	
			4. Signed copy of the executed Post Construction Storm Water Maintenance Agreement and proof of recording	
			Maintenance Report	
			1. **An original and two copies** of the executed maintenance agreement with a map showing property boundaries, address, cross-streets and bounding roadways with names, structures and pavement that will exist onsite after proposed development is complete, and the location and type of all SW BMPs that will be located onsite after the proposed development is complete. Note: if the maintenance agreement submitted with the SWMP is inaccurate due to design or construction changes to SW BMPs, the new maintenance agreement with accurate information must be executed and provided with the record drawing.	
			2. Location and description GIP/BMP protective measures, as applicable	
			3. Description of maintenance requirements for overall storm water functions and for each GIP and BMP, including cleanout, repair, and vegetation replacement, etc.	
			4. Inspection and maintenance checklists for each type of SW BMP that is located on the property	
			5. Manufacturer's identification number, make, model, and size for all proprietary BMPs shown on the plans, including green roofs, pervious pavers, cistern systems, and vendor-supplied underground systems	
			6. Project vegetation plan, showing vegetation types and placement within all vegetated pervious areas. Indicate general plant types (e.g., tree, shrub, grass, flower) and whether native or non-native. Indication of plant species is not preferred but not required.	
			7. Other____	
			Narrative Cover Page	
			1. Project name, address, and contact person	
			2. Name, address, and contact information for person completing checklist	

Post Construction Storm Water Record Drawing Submittal Checklist continued

Yes	No	NA	Item Description and/or Information	City Staff Notes
			3. Post Construction Storm Water Permit Number	
			4. Total project area (in acres)	
			5. Total impervious area as constructed (in acres and square feet)	
			General Information on EACH Record Drawing Page	
			1. Title block with project name, address, and contact person(s)	
			2. Seals and signatures for the certifying Engineer & Surveyor	
			3. Survey benchmarks or other reference point	
			4. North arrow, bar scale, and coordinates	
			5. The following statement along with the registered Engineer's signature and license number: "I hereby certify that all grading, drainage, structures, and/or systems, including facilities and vegetative measures, have been completed in substantial conformance with the approved plans and specifications."	
			Storm Water GIPs and BMPs Report (structural facilities for storm water quality, small storm extended detention, and flood protection)	
			1. Storm water GIPs and BMPs, including storage structures such as detention ponds, shown and properly labeled in keeping with the formal structure names identified in the City of Birmingham Post Construction Storm Water Design manual. Use max. of 2-foot contours with 1-foot contours where detail is needed.	
			2. Inlet structures, properly labeled with locations and invert elevations	
			3. Outlet structures, including all orifices and weirs, properly labeled with size, diameter, invert elevation, means of anchoring, underdrain systems, and method(s) of protection	
			4. Storm water calculations (signed and stamped by the engineer) indicating that the as-constructed conditions meet the approved design as indicated by the approved Post Construction Storm Water Management Plan. Include all inputs and methods.	
			5. Manufacturer's identification number, make, model, and size for all proprietary BMPs shown on the plans, including green roofs, pervious pavers, cistern systems, and vendor-supplied underground systems. (Required both here and in maintenance report above.)	
			6. Project vegetation plan, showing vegetation types and placement within all GIPs and vegetated pervious areas. Indicate general plant types (e.g., tree, shrub, grass, flower) and whether native or non-native. Indication of plant species is not preferred but not required. (Required both here and in the maintenance report above.)	
			End of post-construction storm water requirements for record drawing(s).	

Notes:

CITY OF BIRMINGHAM

Department Of Planning, Engineering & Permits
710 North 20th Street
City Hall|Room 207
Birmingham, Alabama 35203

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RANDALL L. WOODFIN
MAYOR

EDWIN REVELL
DIRECTOR

POST CONSTRUCTION STORM WATER RECORD DRAWING CERTIFICATION FOR ENGINEERS & LANDSCAPE ARCHITECTS

Certification:

I, ____, a licensed (check one below)

☐ Civil Engineer ☐ Landscape Architect

in the State of Alabama, state that, in my professional opinion, the Record Drawing(s), identified by date and address below:

1. Include an accurate representation of all of the post-construction storm water components located at the project, including permanent and final grading/slopes, impervious areas, vegetated pervious areas, permanent storm water drainage systems (both surface and subsurface), green infrastructure practices (if applicable), and/or other permanent best management practices installed to control post-construction storm water quality and/or quantity; and,

2. Represent the as-constructed condition for said post-construction storm water components, including all revisions made necessary by change orders, design modifications, request for information, and/or field orders.

I further state that, based on my calculations and analyses performed using the as-constructed conditions shown in the Record Drawing(s), that the post-construction storm water components installed for this project meet the post-construction storm water performance standards required for the project.

Job Location: ____

(Physical Address)

Job Location (repeat): ____

(Physical Address)

Signature of Licensed Individual: ____

License No.: ______________________________ Date: ______________________________________

Stamp or seal here

Note: If you are unwilling to sign this certification as is, please provide this office with an "adverse effects" letter addressing the issues you have with the certification statement(s) above. If necessary, please provide supporting maps, drawings, calculations, and analyses to support your position.

This statement applies to post-construction storm water components only, as identified in the statement above.

Return to: Department of Planning, Engineering & Permits
Attn: Chief Civil Engineer – Watersheds
710 20th Street North
Room 220
Birmingham Alabama 35203
Telephone: (205) 254-2259
Fax: (205) 254-2023

CITY OF BIRMINGHAM

Department Of Planning, Engineering & Permits
710 North 20th Street
City Hall|Room 207
Birmingham, Alabama 35203

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RANDALL L. WOODFIN
MAYOR

EDWIN REVELL
DIRECTOR

POST CONSTRUCTION STORM WATER RECORD DRAWING CERTIFICATION FOR LAND SURVEYORS

Certification:

I, ____, a licensed LAND SURVEYOR in the State of Alabama, state that the Record Drawing(s), identified by date and address below,

1. Provide an accurate representation of <u>all</u> of the post-construction storm water components located at the project, including permanent and final grading/slopes, impervious areas, vegetated pervious areas, permanent storm water drainage systems (both surface and subsurface), green infrastructure practices (if applicable), and/or other permanent best management practices installed to control post-construction storm water quality and/or quantity; and,

2. Represent the as-constructed condition for said post-construction storm water components.

Job Location: ____
(Physical Address)

Signature of Licensed Individual: ____

License No.: _______________________________ Date: _______________________________________

Stamp or seal here

Note: If you are unwilling to sign this certification as is, please provide this office with an "adverse effects" letter addressing the issues you have with the certification statement(s) above. If necessary, please provide supporting maps, drawings, calculations, and/or analyses to support your position.

This statement applies to post-construction storm water components only, as identified in the statement above.

Return to: Department of Planning, Engineering & Permits
Attn: Chief Civil Engineer – Watersheds
710 20th Street North
Room 220
Birmingham Alabama 35203
Telephone: (205) 254-2259
Fax: (205) 254-2023

CITY OF BIRMINGHAM

Department Of Planning, Engineering & Permits

710 North 20th Street

City Hall|Room 207

Birmingham, Alabama 35203

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RANDALL L. WOODFIN
MAYOR

EDWIN REVELL
DIRECTOR

POST CONSTRUCTION STORM WATER PERMIT TERMINATION CERTIFICATION

Certification:

I, ____, as the current or past (circle one) OWNER or, if not the owner, the DEVELOPER responsible for completion of the PROJECT, identified below by physical address and Post Construction Storm Water Permit number, request closure of the Post Construction Storm Water Permit.

Job Location: ____

(Physical Address)

Post Construction Storm Water Permit No.: ____

In making this request, I attest that:

1. Construction of said project is substantially complete such that all buildings are ready for occupancy or use and all vegetated landscape has been fully installed; and,
2. All post-construction storm water components, including permanent and final grading/slopes, impervious areas, vegetated pervious areas, permanent storm water drainage systems (both surface and subsurface), green infrastructure practices (if applicable) and/or other permanent best management practices installed to control post-construction storm water quality and/or quantity, have been fully installed; and,
3. All pervious areas that were disturbed during construction (e.g., landscaped beds, lawns, meadows, newly reforested areas) have been entirely and fully stabilized with permanent vegetation and that said vegetation is presumed to be in good health; and,
4. All impervious areas are free and clean of sediment, construction-related wastes and debris, and landscape installation-related wastes and debris; and,
5. All permanent storm water drainage systems (both surface and subsurface), green infrastructure practices (if applicable) and permanent best management practices (if applicable) are free and clean of sediment, debris, and other matter that could diminish their full function and proper operation as designed; and,

6. A complete Record Drawing and Record Drawing Certification have been provided for said project; and,
7. The Maintenance Agreement provided with the Record Drawing of said project is complete and accurate as to the information contained thereon.

In signing this request, I am providing a ONE YEAR (12 month) warranty for all vegetation installed as part of this development project, to begin on the date indicated below. I understand that I am responsible for replacement and installation of any and all vegetation supplied and installed by myself, my contractors, and my subcontractors should said vegetation fail to thrive and succeed into the design indicated in the approved Storm Water Management Plan for the project. I understand that the City of Birmingham will visually inspect said vegetation within the 12-month warranty period, that I will be informed in writing if the vegetation is determined by the City to be failing to thrive or believed to be dead, and that I must remove and replace such vegetation within 30 days of written notification by the City of Birmingham or face penalty(s) as indicated in City Code.

I understand that suspected physical and/or chemical damage or neglect in watering or pest control by a future occupant or owner (should ownership of the property be transferred within the 12 month period) does not release me from this warranty. I understand that am responsible for resolving such matters with the occupant or future owner alone, such that problem vegetation is removed and replaced within the required 30-day period.

Signature of Owner/Developer: ____

Date: ____

Return to: Department of Planning, Engineering & Permits
Attn: Chief Civil Engineer – Watersheds
710 20th Street North
Room 220
Birmingham, Alabama 35203
Telephone: (205) 254-2259
Fax: (205) 254-2023

Appendix C

Vegetation and Alabama Native Plant List

C.1 Vegetation Report

A Vegetation Report is required as part of the Storm Water Management Plan. The Storm Water Management Plan Checklist provided in Appendix B lists the required elements of the vegetation report. These include the proposed Green Infrastructure Practice (GIP) template(s), delineation of planting area(s), and specific information on plant types, planting density, sequence, post-nursery care, and initial maintenance. Follow the checklist to ensure that a fully vegetation report is provided. This appendix provides policies for design of the planting areas on the property and preparation of the vegetation report.

C.1.1 Planting Area Definition

The planting area is defined as the portion(s) of the property that will be disturbed by construction events and are intended to permanently remain in a pervious, vegetated condition after construction has ended.

C.1.2 Requirements

Minimum requirements for the vegetation report are listed below.

1. The vegetation report is a scaled construction drawing (typically at 1" = 20'), which accurately locates and represents the plant materials used within the planting areas, including within each GIP proposed for the land development.
2. The vegetation report shall be prepared by a qualified design professional. This is, ideally, a landscape architect or possibly a landscape contractor or management company, provided that they understand GIPs, storm water Best Management Practices (BMPs) and Low Impact Development (LID) storm water control through vegetation and soil management.
3. The vegetation report must address <u>100% of the planting area</u>. Very specific plant and soil information will be required for reforestation areas, stream buffers, soil restoration areas, GIPs, and BMPs, as specified in the policies below. More general information can be provided in other pervious areas.
4. Representation of plant material shall be to scale and depicted at the mature width or spread.
5. For the planting area outside of reforestation areas, stream buffers, soil restoration areas, and vegetated GIPs and BMPs, the vegetation report shall, at a minimum, specify the general vegetation template (i.e., preserved forest, turf, meadow, ornamental landscaped, etc.), installation schedule, and sequence.
6. For reforestation areas, stream buffers, soil restoration areas, and vegetated GIPs and BMPs, the vegetation report shall include, at a minimum:
    a. Accurate location and representation of all vegetation to be installed, including a plant key that identifies all plant material to be used. The symbols used in the key shall correlate with the plant list. Plant groupings are usually shown by an identifying symbol and the number of plants in that particular group.
    b. A plant list, which shall include scientific name, common name, quantity, nursery container size, container type (e.g., bare root, b&b, plug, container, etc.), appropriate planting season, and other information in accordance with the GIP facility-specific planting section and landscape industry standards.
    c. List any other necessary information to communicate special construction requirements, materials, or methods such as specific plants that must be field located or approved by the designer and size or form matching of an important plant grouping.

7. For the entire planting area, the vegetation report shall include, at a minimum:

   a. Soil media specifications. If topsoil is specified, indicate the topsoil stockpile location, including source of the topsoil if imported to the site.

   b. Construction notes with soil/plant installation sequencing and instructions, indication of how installed plants will be protected from construction activities, plant maintenance requirements, and a watering plan denoting the source of water for plant irrigation, how watering will occur, and the responsible party for watering and maintenance.

   c. A description of the landscape contractor's responsibilities.

   d. A minimum two-year warranty period that stipulates requirements for plant survival/ replacement.

C.2 Plant Establishment and Maintenance Requirements

The following policies include requirements for the installation, establishment and maintenance of vegetation installed in the planting area. Specific requirements for restoration areas, stream buffers, soil restoration areas, and vegetated GIPs and BMPs are noted as such.

1. **Plant Establishment:** Site designers shall use the guidance in this appendix and the GIP and BMP specifications established in Chapter 6 to design and establish on-site vegetation in the planting area, in accordance with vegetation report in the approved Storm Water Management Plan. Site designers and construction contractors are encouraged to use other resources for guidance as needed to ensure the establishment of a healthy, growing planting area.

2. **Bare areas prohibited.** Bare soil is prohibited in the planting area as eroding soil can discharge to GIPs, the on-site drainage system, and downstream waterbodies. Clogging of the GIP or drainage system, and sediment pollution in waterbodies can result. Permanent vegetated or mulch cover shall be established as soon as bare areas are noticed.

3. **Irrigation:** Planting design should minimize the need for a permanent irrigation system; however, irrigation is an important aspect of any landscape establishment. New plantings need two to three years of irrigation to become established, but this varies by location and seasonal conditions. Temporary irrigation systems, hand watering, or alternative methods of irrigation must be considered, especially on construction sites. After that period, native plants will need little to no supplemental irrigation. Where permanent irrigation systems are utilized, they shall include a weather-based controller to avoid watering during wet weather. Note that soil in vegetated GIPs and soil restoration areas are formulated (or amended if the latter) to infiltrate, thus water may drain rapidly into the GIP. For these areas, irrigation application rates must be properly designed to avoid overwatering yet prevent potential discharges via underdrains.

4. **Staking:** Provide extra support to trees, especially in high wind areas. They shall be securely staked during establishment and inspected once or twice a year and following storm events. Stakes shall be removed as soon as they are no longer needed to stabilize the tree (between one and two years).

5. **Weeding:** Weeds compete with plants for nutrients, water and sunlight, so it is best to remove them before they can negatively impact the desired vegetation. Weeds shall be regularly removed, with their roots, by hand pulling or with manual pincer-type weeding tools. In vegetated GIPs and soil restoration areas, care shall be given to avoid unnecessary compaction of soils while weeding.

6. **Debris removal:** Leaf litter and trimmings present during maintenance should be removed from soil restoration areas and vegetated GIPs rather than left to decompose as nitrogen levels can be affected and can change the function of the GIP.

7. **Mulching:** Where mulch is specified, mulch should be applied to a depth of one to two-inches to retain moisture, prevent erosion, and suppress weed growth. Reapply annually as the mulch breaks down. Use a compost mulch and avoid bark mulches that can float during storm events. **Synthetic mulches and colored natural mulches are prohibited in GIPs and BMPs.**

8. **Fertilization:** The design for plantings shall minimize the need for herbicides, fertilizers, pesticides, or soil amendments at any time before, during, and after construction and on a long-term basis. Natural fertilization can often be done by applying apply compost mulch once per year in spring or fall, or by spraying compost tea once per year between March and June. Consult a local landscape contractor or nursery for more information on natural fertilization approaches.

9. **Avoiding washout during construction:** Slope stabilization methods (such as planted erosion control mats or fiber rolls) shall be utilized for slopes susceptible to washout. Erosion control mats and fabrics shall also be utilized to protect channels that are susceptible to washing out. Flows shall be diverted temporarily from seeded areas until they are stabilized. Aquatic and safety benches shall be stabilized with emergent wetland plants and wet seed mixes.

10. **Plant Replacement:** Plants that do not survive the two-year warranty period must be replaced to avoid spreading disease, soil erosion, establishment of weeds, and reduced GIP function. It is strongly recommended that plants be checked and replaced in the first year after installation, and then again before the two-year warranty period ends. Before replacing with the same species, determine if another species may be better suited to the conditions.

C.3 Plant Templates

The plant template refers to the form and combination of native trees, shrubs, and perennial ground covers that maintain the appearance and function of the planting area, and more specifically within vegetated GIPs. The choice of which plant template to use depends on the scale of the area or GIP, the context of the site in the urban environment, the filter depth, the desired landscape amenities, and the future owner's capability to maintain the landscape.

In general, the vegetative goal for a vegetated infiltration GIP, such as a bioretention area, is to cover up the filter surface with vegetation in a short amount of time with plants that are sustainable throughout the life of the GIP. This means that the herbaceous layer is equally or more important than widely-spaced trees and shrubs. The goal for other types of GIPs is to stabilize the soil surface and provide other site-specific benefits.

General plant templates are described below.

- **Ornamental.** This option includes perennials, sedges, grasses, shrubs, and/or trees in a mass bed planting. This template is recommended for commercial sites where visibility is important. This template requires maintenance much like traditional landscape beds.

- **Meadow.** This is a lower maintenance approach that focuses on the herbaceous layer and may resemble a wildflower meadow or prairie. The goal is to establish a more natural look that may be appropriate if the facility is in a lower maintenance area (e.g., further from buildings and parking lots). Shrubs and trees may be incorporated. Erosion control matting can be used in lieu of the conventional mulch layer.

Below: Implementation of a meadow plant template.
(Courtesy: RHS Garden Harlow Carr, UK)

- **Reforestation.** This option plants a variety of tree seedlings and saplings where the species distribution is modeled on characteristics of existing local forest ecosystems. Trees are planted in groups with the goal of establishing a mature forest canopy. This template is appropriate for large bioretention areas located at wooded edges, where a wooded buffer is desired, or where the reforestation GIP (see Chapter 6, Section 6.9) is used.

C.4 Plant Layout

C.4.1 Quantity and Spacing

Plant quantity is calculated based on the square feet needed per plant, which is based on whether you plan to arrange plants on a rectangular or triangular or other grid pattern. For rectangular spacing, the space between plants and between rows is the same. Triangular spacing is generally more visually appealing as it creates a mass-planting look and plants are equally spaced within rows, but the rows are staggered. An example of a triangular spacing layout is shown in **Figure C-1** and spacing requirements are shown in **Table C-1**. Refer also to the two design examples below from the *Low Impact Development Handbook for the State of Alabama*.

Figure C-1. Typical Plant Spacing (X equals the distance on center (O.C.) of plant species.)

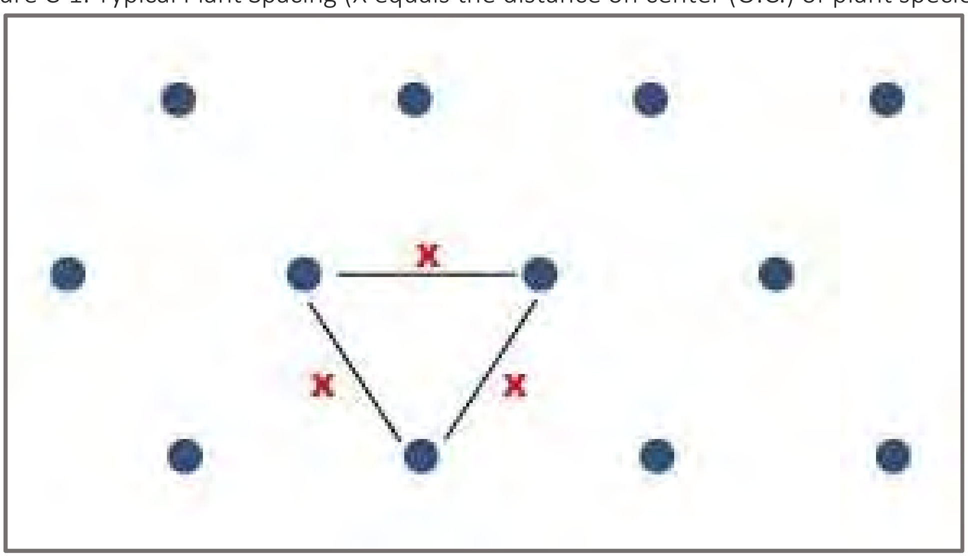


Table C-1. Plant Spacing for Perennials, Grasses, Sedges, and Shrubs

Spacing (O.C.)	Plants per 100 sq. ft.
18”	51.2
24”	29
28”	22
30”	18.5
36”	12.8
42”	10
4’	7.23
5’	4.61
6’	3.2
8’	1.8

C.4.2 General Design Guidance

Vegetation design guidelines include the following:

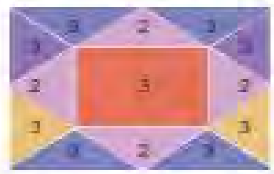
- Mature plant sizes should be considered, both for aesthetics and land cover for the GIP.
- Consider the direction a rain garden will be viewed. If it will be viewed from one side, i.e., a heavily-trafficked sidewalk, it may be appropriate to place taller plants in the back. If the GIP will be viewed from two or more sides, taller plants should be placed in the center.
- Plants are usually clustered in groups of three, five, or seven.
- Be sure to include space between different plantings for maintenance access as well as any reseeding of perennial plants.

Figure C-2. Vegetation Design Example 1 – Standard Bioretention *(Source: Alabama LID Handbook)*

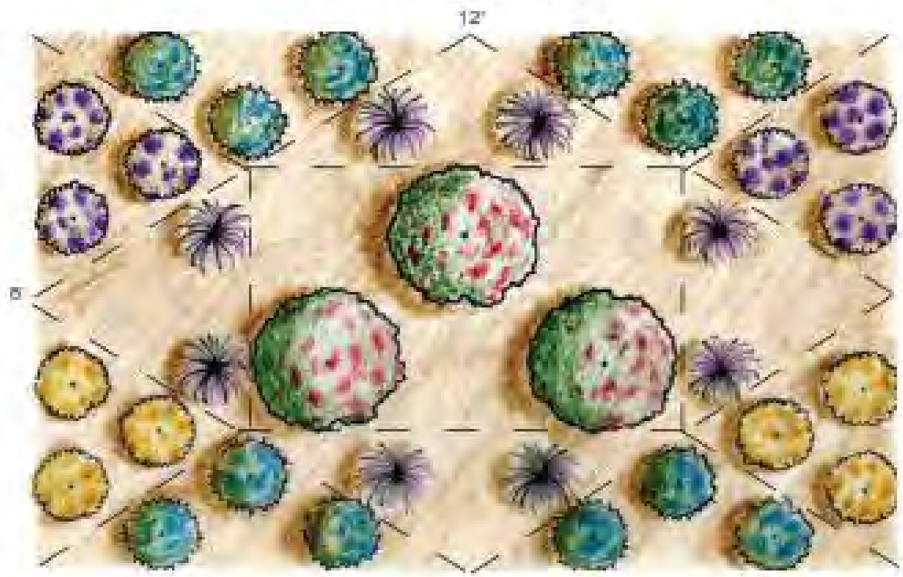
Vegetation Design Example 1

Standard Rain Garden

This rain garden vegetation plan was designed for a front yard with showy plants and seasonal interest. The design calls for a 3" ponding depth and is an 8' x 12' (96 ft²) rectangle on a triangular spacing pattern. The slope and buffer are planted with repurposed turfgrass.



Planting Diagram (ft²)



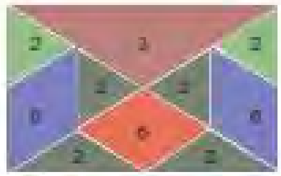
Plant List

Plant Common Name	Spacing (ft)	Area (ft²)	ft²/plant	Quantity
crimsoneyed rose mallow	3	24	7.8	3
muhly grass	2	6	3.4	2
muhly grass	2	6	3.4	2
muhly grass	2	6	3.4	2
muhly grass	2	6	3.4	2
purple coneflower	1.5	6	2	3
purple coneflower	1.5	6	2	3
orange coneflower	1.5	6	2	3
orange coneflower	1.5	6	2	3
Stoke's aster	1.5	6	2	3
Stoke's aster	1.5	6	2	3
Stoke's aster	1.5	6	2	3
Stoke's aster	1.5	6	2	3

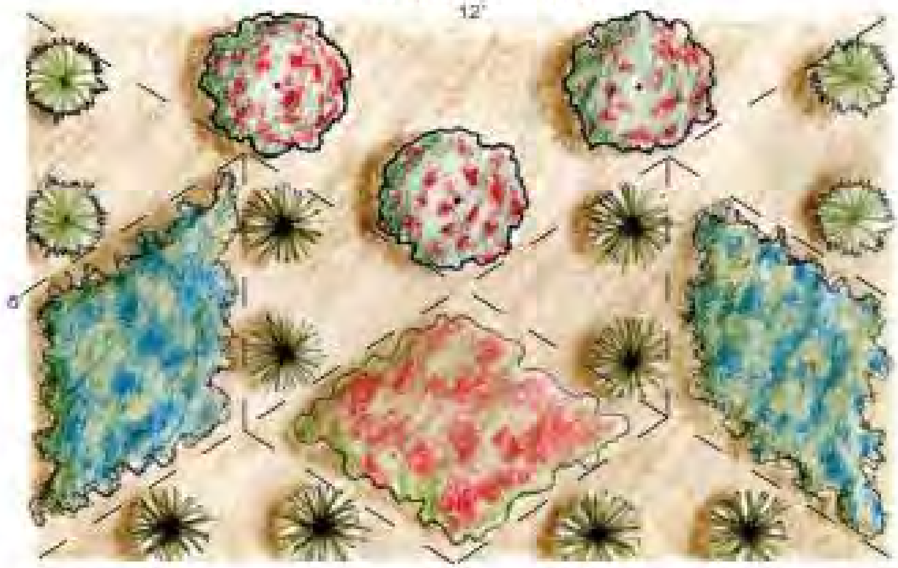
Figure C-3. Vegetation Design Example 2 – Wet Bioretention *(Source: Alabama LID Handbook)*

Vegetation Design Example 2
Wet Rain Garden

This rain garden vegetation plan was designed for a residential back yard. The design calls for a 3" ponding depth and is an 8' x 12' (96 ft²) rectangle on a triangular spacing pattern with standard (level) topography throughout the rain garden. The slope and buffer of this rain garden are planted with muhly grass.



Planting Diagram (ft²)



Plant List

Plant Common Name	Spacing (ft)	Area (ft²)	ft² / plant	Quantity
common rush	2	6	3.4	2
common rush	2	6	3.4	2
common rush	2	6	3.4	2
common rush	2	6	3.4	2
cardinal flower	1.5	12	2	6
cardinal flower	1.5	12	2	6
sweetflag	2	6	3.4	2
sweetflag	2	6	3.4	2
swamp milkweed	1.5	12	2	6
scarlet rose mallow	3	2	7.8	3

C.5 Plant Species Selection

The selection of appropriate species and cultivars is important to maintaining a low-maintenance, attractive, and functional GIP. Native plant species are preferred over non-native species, but some ornamental species may be used for landscaping effect if they are not aggressive or invasive.

Once established, plants in landscaped areas of GIPs should require little maintenance. Native plants are recommended in GIPs because they are low maintenance, sustainable, and already adapted to environmental conditions experienced in these practices. Native herbaceous perennial plants usually reseed themselves or spread by vegetative offsets to maintain landscape cover over time. Although native seed plantings may be slow to establish and more expensive compared to nonnative plants, their persistence makes them a cost-effective choice. In addition to experiencing repeated flood events in GIPs, plants may also be exposed to extended periods of drying. Drought tolerant plants can maintain photosynthesis and transpiration during a drought and this allows them to continue to efficiently produce carbohydrates necessary for growth, which correlates to plant survival and recovery following a drought. All plants need irrigation until established or if there is a severe drought, but once established, these plants should rely solely on storm water received.

Many nurseries may grow native plant cultivars instead of the original plant species, which could result in a loss of genetic diversity. Consider goals of the site or project to determine whether a straight species or a cultivar is appropriate. In a constructed storm water wetland, genetic diversity and species richness can be prioritized to enhance habitat, insect, and animal diversity. However, in commercial or residential settings, native plant cultivars may be preferred due to specific ornamental qualities they possess. Practices such as bioretention areas, rain gardens, or swales may also utilize a cultivar due to sight or sizing constraints of the site. Constructed storm water wetlands and wet swales require plants that are tolerant of flooded conditions. GIPs are in high visibility areas, especially in municipal, commercial, or residential community settings, so plants in these practices need to maintain visual quality.

In additional to using landscape professionals and knowledge of specific species and their adaptations, plant trials or screenings of vegetation in GIPs can also provide sound plant recommendations. Specific soil types and textures as well as local microclimates on site may affect performance of vegetation.

C.6 Native Plant Species Lists

Native plant species are preferred over non-native species, but some ornamental species may be used for landscaping effect if they are not aggressive or invasive. **Tables C-2 to C-11** list native plant species suitable for use in the GIP indicated. These species may also be used in other applications. Refer to additional information in the *Low Impact Development Handbook for the State of Alabama*, the Alabama Plant Atlas (www.floraofalabama.org) and the Alabama Cooperative Extension System (www.aces.edu).

Table C-2. Popular Native Perennials for Bioretention – Full Sun

Latin Name	Common Name	Size	Spacing	Moisture	Color	Height
Asclepias incarnata	Marsh milkweed	Plugs – 1 gal.	1 plant/24" o.c.	Wet	Pink	3-4'
Asclepias longifolia	Longleaf milkweed	Plugs – 1 gal.	1 plant/18" o.c.	Wet-Moist	White	2-4'
Chamaecrista fasciculata	Partridge pea	Plugs – 1 gal.	1 plant/18" o.c.	Dry	Yellow	1-2'
Conoclinium coelestinum	Mist flower	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Blue	1-2'
Coreopsis lanceolata	Lance-leaf coreopsis	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Yellow	6-8'
Echinacea purpurea	Purple coneflower	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Purple	3-4'
Eupatorium purpureum	Sweet Joe-Pye Weed	Plugs – 1 gal.	1 plant/24" o.c.	Wet-moist	Purple	3-6'
Impatiens capensis	Jewelweed	Plugs – 1 gal.	1 plant/18" o.c.	Moist	Blue-violet	3'
Iris virginica	Flag Iris	Plugs – 1 gal.	1 plant/18" o.c.	Moist-Wet	Blue	2'
Liatris aspera	Rough blazingstar	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Purple	2-5'
Lobelia cardinalis	Cardinal flower	Plugs – 1 gal.	1 plant/18" o.c.	Wet-moist	Red	2-4'
Lobelia puberula	Lobelia	Plugs-1 gal.	1 plant/18" o.c.	Moist	Blue-violet	2-4'
Monarda didyma	Bee balm	Plugs – 1 gal.	1 plant/24" o.c.	Wet-moist	Red	3'
Penstemon digitalis	Smooth white beardtongue	Plugs – 1 gal	1 plant/24" o.c.	Wet	White	2-3'
Rudbeckia hirta	Black-eyed Susan	Plugs – 1 gal	1 plant/18" o.c.	Moist-dry	Yellow	3'
Salvia coccinea	Texas sage	Plugs – 1 gal	1 plant/18" o.c.	Moist-dry	Red	1-3'
Solidago nemoralis	Gray goldenrod	Plugs – 1 gal.	1 plant/18" o.c.	Dry	Yellow	2'
Solidago rugosa	Rough-leaved goldenrod	Plugs – 1 gal.	1 plant/18" o.c.	Wet	Yellow	1-6'

Plant material size and grade to conform to "American Standards for Nursery Stock" American Association of Nurserymen, Inc. latest approved revision, ANSI Z-60-1

Table C-3. Popular Native Perennials for Bioretention – Shade

Latin Name	Common Name	Size	Spacing	Moisture	Color	Height
Aquilegia canadensis	Wild columbine	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Pink	1-2.5'
Athyrium filix-femina	Lady Fern	1 gal.	1 plant/18" o.c.	Moist	Green	3'
Arisaema triphyllum	Jack-in-the-pulpit	Plugs – 1 gal.	1 plant/18" o.c.	Moist	Green	1.5-2.5'
Arisaema dricontium	Green dragon	Plugs – 1 gal.	1 plant/18" o.c.	Wet-moist	Green	3'
Asarum canadense	Wild ginger	Plugs – 1 gal.	1 plant/18" o.c.	Wet-moist	Red-brown	0.5-1'
Coreopsis major	Tickseed coreopsis	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Yellow	3'
Dryopteris marginalis	Shield Fern	1 gal.	1 plant/18" o.c.	Moist	Green	2-3'
Geranium maculatum	Wild geranium	Plugs – 1 gal.	1 plant/18" o.c.	Moist	Pink	2'
Heuchera americana	Alumroot	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Purple	1'
Iris cristata	Dwarf crested iris	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Purple	4"
Lobelia siphilicata	Great blue lobelia	Plugs – 1 gal.	1 plant/18" o.c.	Wet-moist	Blue	1.5-3'
Lobelia cardinalis	Cardinal flower	Plugs – 1 gal.	1 plant/18" o.c.	Wet-moist	Red	2-4'
Mertensia virginica	Virginia bluebells	Plugs – 1 gal.	1 plant/18" o.c.	Moist	Blue	1.5'
Osmunda cinnamomea	Cinnamon Fern	1 gal.	1 plant/24" o.c.	Wet-moist	Green	3-4'
Phlox divericata	Blue phlox	Plugs – 1 gal.	1 plant/18" o.c.	moist	Blue	0.5-2'
Polemonium reptans	Jacob's ladder	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Blue	15"
Polystichum acrostichoides	Christmas fern	Plugs – 1 gal.	1 plant/24" o.c.	Moist-dry	Ever-green	2'

Plant material size and grade to conform to "American Standards for Nursery Stock" American Association of Nurserymen, Inc. latest approved revision, ANSI Z-60-1.

Table C-4. Popular Native Grasses and Sedges for Bioretention

Latin Name	Common Name	Size	Spacing	Moisture	Color	Height
Carex comosa	Bottlebrush sedge	1 gal.	1 plant/24" o.c.	Wet	Green	3.5'
Carex stricta	Tussock Sedge	1 gal.	1 plant/24" o.c.	Moist	Green	3-4'
Carex tribuloides	Blunt broom sedge	1 gal.	1 plant/24" o.c.	Moist-wet	Green	3'
Chasmanthium latifolium	Upland Sea Oats	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Green	4'
Juncus effesus	Soft Rush	Plugs – 1 gal.	1 plant/24" o.c.	Wet-dry	Green	4-6'
Muhlenbergia capallaris	Muhly Grass	1 gal.	1 plant/24" o.c.	Moist	Pink	3'
Panicum virgatum	Switchgrass	1-3 gal.	1 plant/48" o.c.	Moist-dry	Yellow	5-7'
Schizachyrium scoparium	Little Blue Stem	1 gal.	1 plant/24" o.c.	Moist-dry	Yellow	3'

Plant material size and grade to conform to "American Standards for Nursery Stock" American Association of Nurserymen, Inc. latest approved revision, ANSI Z-60-1.

Table C-5. Popular Native Trees for Bioretention

Latin Name	Common Name	DT/FT	Light	Moisture	Notes	Flower Color	Height
Acer rubrum	Red Maple	DT-FT	Sun-shade	Dry-wet	Fall color		50-70'
Acer saccharum	Sugar Maple		Sun-pt shade	Moist	Fall color		50-75'
Ameleanchier Canadensis	Serviceberry		Sun-pt shade	Moist-wet	Eatable berries	White	15-25'
Asimina triloba	Paw Paw		Sun-pt shade	Moist	Eatable fruits	Maroon	15-30'
Betula nigra	River Birch	FT	Sun-pt shade	Moist-wet	Exfoliating bark		40-70'
Carya glabra	Pignut Hickory		Sun-pt shade	Moist	Fall color		50-60'
Cercus Canadensis	Redbud	DT	Sun-shade	Moist	Pea-like flowers, seed pods	Purple	20-30'
Chionanthus virginicus	Fringetree		Sun-pt shade	Moist	Panicled, fragrant flowers	White	12-20'
Cladratis lutea	Yellowwood	DT	Sun	Dry-moist	Fall color	White	30-45'
Cornus florida	Flowering Dogwood		Part shade	Moist	Red fruit, wildlife	White	15-30'
Ilex opaca	American Holly	DT	Sun-pt shade	Moist	Evergreen	White	30-50'
Liquidambar styraciflua	Sweetgum	DT-FT	Sun-pt shade	Dry-moist	Spiny fruit		60-100'
Magnolia virginiana	Sweetbay Magnolia		Sun-pt shade	Moist-wet	Evergreen	White	10-60'

Table C-5. Popular Native Trees for Bioretention

Latin Name	Common Name	DT/FT	Light	Moisture	Notes	Flower Color	Height
Nyssa sylvatica	Black Gum		Sun-Shade	Moist	Fall color		35-50'
Oxydendrum arboretum	Sourwood		Sun-pt shade	Dry-moist	Wildlife	White	20-40'
Platanus occidentalis	Sycamore	FT	Sun-pt shade	Moist	White mottled bark		70-100'
Quercus bicolor	Swamp White Oak	DT	Sun-pt shade	Moist-wet	Acorns		50-60'
Quercus lyrata	Overcup Oak	FT	Sun	Moist	Acorns		40-60'
Quercus shumardii	Shumard Oak	DT	Sun	Moist	Acorns		40-60'
Quercus stellate	Post oak		Sun-pt shade	Dry			40-50'
Rhamnus caroliniana	Carolina Buckthorn		Sun	Moist	Black fruit		15-30'
Ulmus americana	American Elm	DT-FT	Sun-pt shade	Moist			

Size: min. 2" caliper if not reforestation. DT: Drought Tolerant. FT: Flood Tolerant. Plant material size and grade to conform to "American Standards for Nursery Stock" American Association of Nurserymen, Inc. latest approved revision, ANSI Z-60-1.

Table C-6. Popular Native Shrubs for Bioretention

Latin Name	Common Name	DT/FT	Light	Moisture	Spacing (O.C.)	Notes	Flower Color	Height
Aronia arbutifolia	Red Chokeberry	FT	Sun-pt shade	Dry-wet	4'	Red berries, wildlife	White	6-12'
Callicarpa Americana	American Beautyberry	DT	Sun-pt shade	Dry-wet	5'	Showy purple fruit	Lilac	4-6'
Cephalanthus occidentalis	Button Bush	FT	Sun-shade	Moist-wet	5'	Attracts wildlife	White	6-12'
Cornus amomum	Silky Dogwood		Sun-shade	Moist-wet	6'	Blue berries, wildlife	White	6-12'
Corylus americana	American Hazelnut		Sun-pt shade	Dry-moist	8'	Eatable nuts, wildlife	Yellow	8-15'
Hamemelis virginiana	Witch-hazel		Sun-pt shade	Dry-moist	8'	Winter bloom	Yellow	10'
Hydrangea quercifolia	Oakleaf Hydrangea	DT	Pt shade – shade	Moist	4'	Winter texture	White	3-6'
Hypericum prolificum	Shrubby St. John's Wort	DT	Sun-pt shade	Dry-moist	3'	Semi-evergreen	Yellow	3'
Ilex decidua (dwarf var.)	Possumhaw Viburnum	DT	Sun-pt shade	Moist	4-6'	Red berries		6-14'
Ilex glabra	Inkberry	DT	Sun-pt shade	Moist-wet	3'	Evergreen		4-8'
Ilex verticillata	Winterberry Holly	FT	Sun-pt shade	Moist-wet	3'	Red berries		10'

Table C-6. Popular Native Shrubs for Bioretention

Latin Name	Common Name	DT/FT	Light	Moisture	Spacing (O.C.)	Notes	Flower Color	Height
Itea virginica	Virginia Sweetspire	DT-FT	Sun-shade	Moist-wet	4’	Fall color	White	4-8’
Lindera benzoin	Spicebush	DT	Pt shade – shade	Moist-wet	8’	Butterflies, wildlife	Yellow	6-12’
Viburnum dentatum	Arrowwood Viburnum		Sun-shade	Dry-wet	6’	Wildlife	White	6-8’

Size: minimum 3 gal. container or equivalent. DT: Drought Tolerant. FT: Flood Tolerant. This list provides plant species; there are multiple varieties within each species. Plant material size and grade to conform to “American Standards for Nursery Stock” American Association of Nurserymen, Inc. latest approved revision, ANSI Z-60-1.

Popular Plants Suitable for Tree Planters in Birmingham

Table C-7. Popular Native Perennials Suitable for Tree Planters – Full Sun

Latin Name	Common Name	Size	Spacing	Moisture	Color	Height
Asclepias tuberosa	Butterfly milkweed	Plugs – 1 gal.	1 plant/18” o.c.	Dry-moist	Orange	2’
Coreopsis lanceolata	Lance-leaf coreopsis	Plugs – 1 gal.	1 plant/18” o.c.	Moist-dry	Yellow	6-8’
Echinacea purpurea	Purple coneflower	Plugs – 1 gal	1 plant/24” o.c.	Moist-dry	Purple	3’
Iris virginica	Flag Iris	Plugs – 1 gal.	1 plant/18” o.c.	Moist-Wet	Blue	2’
Liatris spicata	Dense blazingstar	Plugs – 1 gal.	1 plant/24” o.c.	Wet-moist	Purple	1.5’
Penstemon digitalis	Smooth white beardtongue	Plugs – 1 gal	1 plant/24” o.c.	Wet	White	2-3’
Salvia coccinea	Texas sage	Plugs – 1 gal	1 plant/18” o.c.	Moist-dry	Red	1-3’
Solidago rugosa	Winkle-leaf goldenrod	Plugs – 1 gal	1 plant/24” o.c.	Moist-dry	Yellow	2-5’

Table C-8. Popular Native Perennials Suitable for Tree Planters – Shade

Latin Name	Common Name	Size	Spacing	Moisture	Color	Height
Aquilegia canadensis	Wild columbine	Plugs – 1 gal.	1 plant/18” o.c.	Moist-dry	Pink	1-2.5’
Aster oblongifolius *Aster oblongifolius*	Aromatic Aster	Plugs – 1 gal.	1 plant/24” o.c.	Moist-dry	Blue/ purple	1.5-3’
Commelina erecta	Whitemouth dayflower	Plugs – 1 gal.	1 plant/24” o.c.	Dry	Blue	1-3’
Coreopsis lanceolata	Tickseed coreopsis	Plugs – 1 gal.	1 plant/18” o.c.	Moist-dry	Yellow	3’
Heuchera americana	Alumroot	Plugs – 1 gal.	1 plant/18” o.c.	Moist-dry	Purple	1’
Solidago rugosa	Winkle-leaf goldenrod	Plugs – 1 gal	1 plant/24” o.c.	Moist-dry	Yellow	2-5’

Table C-9. Popular Native Grasses and Sedges Suitable for Tree Planters

Latin Name	Common Name	Size	Spacing	Moisture	Color	Height
Carex tribuloides	Blunt broom sedge	1 gal.	1 plant/24" o.c.	Moist-wet	Green	3'
Chasmanthium latifolium	Upland Sea Oats	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Green	4'
Elymus hystrix	Eastern bottlebrush grass					
Juncus effesus	Soft Rush	Plugs – 1 gal.	1 plant/24" o.c.	Wet-dry	Green	4-6'
Muhlenbergia capallaris	Muhly Grass	1 gal.	1 plant/24" o.c.	Moist	Pink	3'
Panicum virgatum	Switchgrass	1-3 gal.	1 plant/48" o.c.	Moist - dry	Yellow	5-7'
Schizachyrium scoparium	Little Blue Stem	1 gal.	1 plant/24" o.c.	Moist-dry	Yellow	3'
Sporobolus heterolepsis	Prairie Dropseed	1 gal.	1 plant/24" o.c.	Moist-dry	Green	2-3'

Table C-10. Popular Native Trees Suitable for Tree Planters

Latin Name	Common Name	DT-FT	Light	Moisture	Notes	Flower Color	Height
Acer rubrum	Red Maple	DT-FT	Sun-shade	Dry-wet	Fall color		50-70'
Betula nigra	River Birch	FT	Sun-pt shade	Moist-wet	Exfoliating bark		40-70'
Carya glabra	Pignut Hickory		Sun-pt shade	Moist	Fall color		50-60'
Cercus Canadensis	Redbud	DT	Sun-shade	Moist	Pea-like flowers, seed pods	Purple	20-30'
Liquidambar styraciflua	Sweetgum (fruitless)	DT-FT	Sun-pt shade	Dry-moist			60-100'
Nyssa sylvatica	Black Gum		Sun-Shade	Moist	Fall color		35-50'
Platanus occidentalis	Sycamore	FT	Sun-pt shade	Moist	White mottled bark		70-100'
Quercus stellate	Post oak		Sun-pt shade	Dry			40-50'
Quercus lyrata	Overcup Oak	FT	Sun	Moist	Acorns		40-60'
Quercus shumardii	Shumard Oak	DT	Sun	Moist	Acorns		40-60'
Ulmus americana	American Elm	DT-FT	Sun-pt shade	Moist			

DT: Drought Tolerant. FT: Flood Tolerant.

Table C-11. Popular Native Shrubs Suitable for Tree Planters

Latin Name	Common Name	DT-FT	Light	Moisture	Notes	Flower Color	Height
Clethra alnifolia	Sweet Pepper Bush (Dwarf)		Sun-pt shade	Dry-moist	Hummingbirds	White	5-8’
Hydrangea quercifolia	Oakleaf Hydrangea (Dwarf)	DT	Pt shade – shade	Moist		White	3-6’
Hypericum prolificum	Shrubby St. John’s Wort		Sun-pt shade	Moist		Yellow	1-5’
Ilex glabra	Inkberry (Dwarf)	DT	Sun-pt shade	Moist-wet	Evergreen		4-8’

DT: Drought Tolerant. FT: Flood Tolerant.

References

Alabama Department of Environmental Management (ADEM), in cooperation with the Alabama Cooperative Extension System and Auburn University. *Low Impact Development Handbook for the State of Alabama*.

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Appendix D
Soil, Karst, and Hotspot Guidelines

D.1 Introduction

The ability of soil to store and release water and sustain vegetation can be limited by a number of land type and surface and subsurface characteristics. Knowledge of the existing soil and the presence of karst or hotspot areas is important for the selection and success of Green Infrastructure Practices (GIPs). Soils that are low in nutrients or poorly drained may be limiting for some vegetated GIPs, rendering them inappropriate or necessitating soil amendment or the use of an underdrain. Development located in karst or hotspot areas shall prevent discharge directly to groundwater to prevent contamination. This appendix outlines the guidelines for soil, karst, and hotspots.

D.2 Soil Guidelines

Suitable soil standards are critical for the effectiveness of GIPs on a development site. Good soil conditions are critical to survival of vegetation on GIPs and any other post-construction vegetation. The soil's infiltration rate is important for the selection and success of GIPs and is described in Appendix E. In addition to the benefits of infiltrating and filtering storm water, adequate permeability also promotes root growth and allows vegetation to obtain adequate air and water.

Plants require the correct range of nutrients to survive and grow. The United States Department of Agriculture (USDA) Web Soil Survey shall be used to identify soil map units and obtain information about soil conditions, including fertility and suitable vegetation. However, since most soil map units have inclusions of other soils that may be quite different, detailed evaluations should be made at the proposed site by a professional soil scientist or soil classifier. The Soil Survey shows that large portions of the City have the soil type of "urban land," which is synonymous with compacted, low fertility soils that can impair vegetation from germination and sustaining healthy growth. Site soil should therefore always be evaluated prior to construction and soil amendments conducted prior to planting. Engineered soil media, compost amendments, and/or nutrient amendments are often required on a development site.

Engineered Soil Media

Several GIPs (bioretention, urban bioretention, dry water quality swale/enhanced swale) require engineered soil media regardless of the existing soil on the site. The recommended soil mixture is generally classified as a loamy sand on the USDA Texture Triangle with the following composition by volume:

- Maximum 60% sand;
- Less than 40% silt;
- 5% to 10% organic matter; and
- Less than 20% clay.

Green roofs also require engineered soil media with specific compositions for extensive and intensive green roofs (see Chapter 6, Section 6.10). ***The engineered soil media and existing soils shall be tested and amended according to the nutrient amendments guidelines below.***

Nutrient Amendments

Vegetation may benefit from compost amendment due to nutrient availability. The use of native plants and the landscaping design shall minimize the need for herbicides, fertilizers, pesticides, or soil amendments at any time before, during, and after construction and on a long-term basis. Nutrient concentrations in storm water are often adequate to establish and maintain plantings; therefore, minimal fertilizer application is permitted.

To meet the nutrient needs of plants post-construction, the following procedures shall be followed:

- A compost top dressing or application of compost tea shall be used to introduce nutrients and beneficial microorganisms to the soil prior to planting vegetation in vegetated GIPs.
- The compost shall be the result of the biological degradation and transformation of plant-derived materials under conditions that promote anaerobic decomposition. The material shall be well-composted, free of viable weed seeds, and have stable oxygen consumption and carbon dioxide generation.
- The compost shall have a moisture content that has no visible free water or dust produced when handling the material. It shall meet the following criteria, as reported by the U.S. Composting Council STA Compost Technical Data Sheet:
  - 100% of the material must pass through a half-inch screen.
  - The pH of the material shall be between 6 and 8.
  - Manufactured inert material (plastic, concrete, ceramics, metal) shall be less than 1.0% by weight.
  - The organic matter content shall be between 35% and 65%.
  - Soluble salt content shall be less than 6.0 Millimhos per centimeter.
  - Maturity should be greater than 80%.
  - Stability shall be 7 or less.
  - Carbon/nitrogen ratio shall be less than 25:1.
  - Trace metal test result = "pass"
  - The compost must have a dry bulk density ranging from 40 to 50 pounds per cubic foot.
- Prior to planting, a soil sample shall be collected for a soil test to determine any additional fertilizer or lime requirements needed for plant establishment at each GIP and for any other vegetated areas of the development site. Submit the soil sample to the Auburn University Soil Testing Laboratory or other comparable soil testing lab. The soil test will indicate any fertilizer or lime requirements that should be mixed into the soil prior to planting.
- Based on the soil test results, a one-time fertilizer application (top dressed on soil surface) prior to planting may be needed to aid in plant establishment, but ongoing fertilization should not be required. Controlled release fertilizers have shown to be effective for plant establishment at rates as low as 3.5 ounces per 20 square feet (13N–6P–11K).
- Apply compost once per year in spring or fall or spray apply compost tea once per year between March and June.
- Soil testing shall be conducted every three to five years following construction to determine if additional lime or fertilizer application is required. Following plant establishment, fertilizers and lime shall not be applied to areas with high velocities or runoff potential, such as grassed filter strips and GIP outlet points, as this can result in the runoff of nutrients.

Soil Compost Amendments

Several GIPs (grass channel, sheet flow, and reforestation) have increased runoff reduction capability with soil compost amendments. The following design criteria apply when compost amendments are used to increase runoff reduction:

- The compost-amended strip should extend over the length and width of the GIP.
- Compost shall be incorporated at the appropriate depth, as determined by the contributing impervious cover to soil amendment area ratio (see **Table D-1**).

- Compost shall be incorporated in appropriate quantities as determined by **Equation 1** below.
- The compost amended area shall be rapidly stabilized to retain the compost and prevent erosion.
- The West Virginia Stormwater Management & Design Guidance Manual includes information on the compost application rates and depths for storm water GIPs in its Appendix D. This information is summarized in **Table D-1** and Equation 1 below.
- Appropriate method of incorporating compost depends on the depth of incorporation per **Table D-1**.

Table D-1. Method to Determine Compost and Incorporation Depth

	Contributing Impervious Cover to Soil Amendment Area Ratio[1]			
	IC/SA=0[2]	IC/SA=0.5	IC/SA=0.75	IC/SA=1.0[3]
Compost (in)[4]	2 to 4[5]	3 to 6[5]	4 to 8[5]	6 to 10[5]
Incorporation Depth (in)	6 to 10[5]	8 to 12[5]	15 to 18[5]	18 to 24[5]
Incorporation Method	Rototiller	Tiller	Subsoiler	Subsoiler

[1] IC = contrib. impervious cover (sq. ft.) and SA = surface area of compost amendment (sq. ft.)
[2] For amendment of compacted lawns that do not receive off-site runoff
[3] In general, IC/SA ratios greater than 1 should be avoided.
[4] Average depth of compost added
[5] Lower end for B soils, higher end for C/D soils

Once the area and depth of the compost amendments are known, the designer shall estimate the total amount of compost needed using Equation 1.

Equation 1. Amount of Compost Needed for Application

$$C = A * D * 0.0031$$

Where:

C = compost needed (cubic yards)
A = area of soil amended (square feet)
D = depth of compost added (inches)

D.3 Karst Guidelines

Karst is a kind of topography that formed in limestone, gypsum, or other soluble rocks by dissolution and that is characterized by closed depressions, sinkholes, caves, and underground drainage. Karst terrain is found in some areas of Birmingham and complicates both land development and storm water design. A detailed geotechnical investigation is required for any kind of storm water design in karst terrain. The use of Level 2 (i.e. infiltration) GIP designs at sites with known karst features may cause the formation of sinkholes (especially for large scale pavement applications) and is, therefore, not permitted. Micro-scale and small-scale permeable pavement installations are acceptable if they are designed according to the Level 1 criteria (i.e., they possess an impermeable bottom liner and an underdrain). The stone used in the reservoir layer shall be carbonate in nature to provide extra chemical buffering capacity.

D.4 Hotspot (Brownfields, etc.) Guidelines

This section defines hotspots and the associated requirements and restrictions for storm water management. Every development site shall be evaluated to determine if it is a hotspot. If the site is determined to be a hotspot, GIP/BMP requirements and restrictions on the use of infiltration practices apply. Hotspots are historic or proposed land uses or activities that generate highly contaminated runoff (concentrations of pollutants more than those typically found in storm water) and/or have a greater risk for spills, leaks, or illicit discharges. A site may be a hotspot due to the potential for groundwater or storm water pollution.

Chapter 4 outlines the water quality requirements for all development sites. Additional BMPs and restrictions for hotspots are required due to the potential for contaminants to leave these sites and contaminate surface water or groundwater. The following paragraphs define five general categories of hot spots and the corresponding requirements and restrictions. A more detailed, but not comprehensive, list of hot spots is included in **Table D-2**. In addition to requirements in this section, sites shall be developed and operated in accordance with applicable National Pollutant Discharge Elimination System (NPDES) permits (40 CFR 122.26 (1994)), underground storage tank regulations, Spill Prevention, Control, and Countermeasures (SPCC) Regulations, and/or other state and federal permits.

- The City maintains a Source Water Assessment Plan per Alabama Administrative Code Chapter 335-7-15 and it is available for review at Birmingham Water Works during normal business hours.
- Fueling areas, including retail gasoline outlets and municipal, state, federal, or institutional refueling areas, shall have BMPs, including (as applicable) covering of storage/handling areas, secondary containment of chemicals, spill containment and control, and other best available technologies. Fueling areas shall have appropriate practices to reduce lead, copper, zinc, and polyaromatic hydrocarbons in storm water run-off.
- Water treatment BMPs, such as filters and oil/water separators, are recommended to improve runoff water quality and prevent illicit discharges. A treatment train removing gross debris (i.e. a catch basin), oil (i.e. an oil/water separator), total suspended solids (i.e. a sediment basin), and then dissolved metals and hydrocarbons (i.e. a sand filter) is recommended. Due to the potential for fuel spills and contaminated runoff, infiltration practices are not permitted.
- Brownfield sites are parcels of real estate that are abandoned, inactive, or may not be operated at its appropriate use and on which expansion, redevelopment, or reuse is complicated because of the presence or potential presence of a hazardous substance, pollutant, or contaminant, including petroleum products, that poses a risk to human health and the environment. Site-specific, post-construction BMPs, including (as applicable) limiting exposure of contaminated areas, spill containment and control, and other best available technologies, are required to prevent mobilization of these hazardous substances or pollutants. If there is the potential for groundwater contamination, an impermeable liner and underdrain shall be used to prevent groundwater contamination from infiltration GIPs.
- Other sites with storage or land use practices that generate highly contaminated runoff and/or have a greater risk for spills, leaks, or illicit discharges are also hot spots. Site-specific, post-construction BMPs, including (as applicable) covering of storage/handling areas, secondary containment of chemicals, spill containment and control, and other best available technologies, are required. Water treatment BMPs, such as filters and oil/water separators, are recommended to improve runoff water quality and prevent illicit discharges. If there is the potential for groundwater contamination, infiltration practices are not permitted. Examples include the following:
    - Vehicle/equipment storage/maintenance areas
    - Waste/recycling storage areas, industrial areas
    - Areas where large quantities of fertilizers or pesticides are used/stored,
    - Areas that store or utilize oils/chemicals

Table D-2 presents a list of potential site uses and areas that may be designated as hot spots. Some sites, as indicated by the table, require specific BMPs to manage potential pollutants. Due to the potential for contamination of soil or groundwater, some sites are restricted from using full infiltration practices. A site may fall into more than one hot spot category and must then follow any restriction on infiltration and implement the required BMPs. For example, a site located in a drinking water source area has BMP requirements if it also falls into another hot spot category. It should be noted that restrictions based on site use may not apply to some "clean" areas of the development (such as rooftops) from which runoff can be diverted.

Table D-2. Hotspots and Associated Infiltration Restrictions and BMP Requirements

Potential Storm Water Hotspot	Infiltration Restriction	BMP Requirement
SITE USE		
Auto and metal recyclers/scrap yards	○	▣
Brownfield sites	◉	◘
Car washes	○	▣
Construction business (paving, heavy equipment storage and maintenance	◉	▣
Convenience stores/fast food restaurants	◉	▣
Facilities w/NPDES Industrial permits	◉	▣
Fleet storage areas	○	▣
Fueling areas	○	▣■
Gas stations	○	▣■
Golf courses	◉	▣
Highway maintenance facilities	○	▣
Industrial yards, machinery and/or equipment	◉	▣
Nurseries and garden centers	◉	▣
Parking lots (40 or more parking spaces)	◉	▣
Petroleum storage facilities	○	▣
Public works yard	○	▣
Retail/wholesale vehicle/ equipment dealers	◉	▣
Shipping and receiving yards	○	▣
Storage areas for raw materials and intermediate products	◉	▣
Trucks and trailers	◉	▣
Vehicle maintenance facilities	○	▣
Wastewater, solid waste and composting facilities	○	▣

Key:

○ Infiltration not permitted. Impermeable liner shall be used for GIP.
◉ Infiltration may or may not be permitted, depending on selected GIP and hotspot facility.
▣ Site specific BMPs, such as covering of storage/handling areas, secondary containment of chemicals, spill containment and control, and other best available technologies required. Water treatment BMPs recommended.
◘ Practices to limit exposure of contaminated areas required.
■ Practices to reduce lead, copper, zinc, and polyaromatic hydrocarbons in storm water run-off required.

References

Center for Watershed Protection and West Virginia Department of Environmental Protection. West Virginia Stormwater Management & Design Guidance Manual. November 2012.

USDA and NRCS. 2007. Part 630 Hydrology National Engineering Handbook, Chapter 7 Hydrologic Soil Groups. Accessed 05 July 2013. http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba

Appendix E
Infiltration Guidelines

E.1 Importance of Infiltration

The infiltration rate of the native soil is important for the selection and success of Green Infrastructure Practices (GIPs). Poorly drained soils may be limiting for some GIPs, rendering them inappropriate or necessitating soil amendment or the use of an underdrain. Infiltration testing is required for all infiltration practices unless an underdrain is used. The results of the infiltration testing are to determine what GIPs are appropriate, if soil amendments are necessary, and whether an underdrain is required. More information on how soil amendments can improve nutrient availability, infiltration rate, and runoff reduction rate for a GIP is included in **Appendix D.**

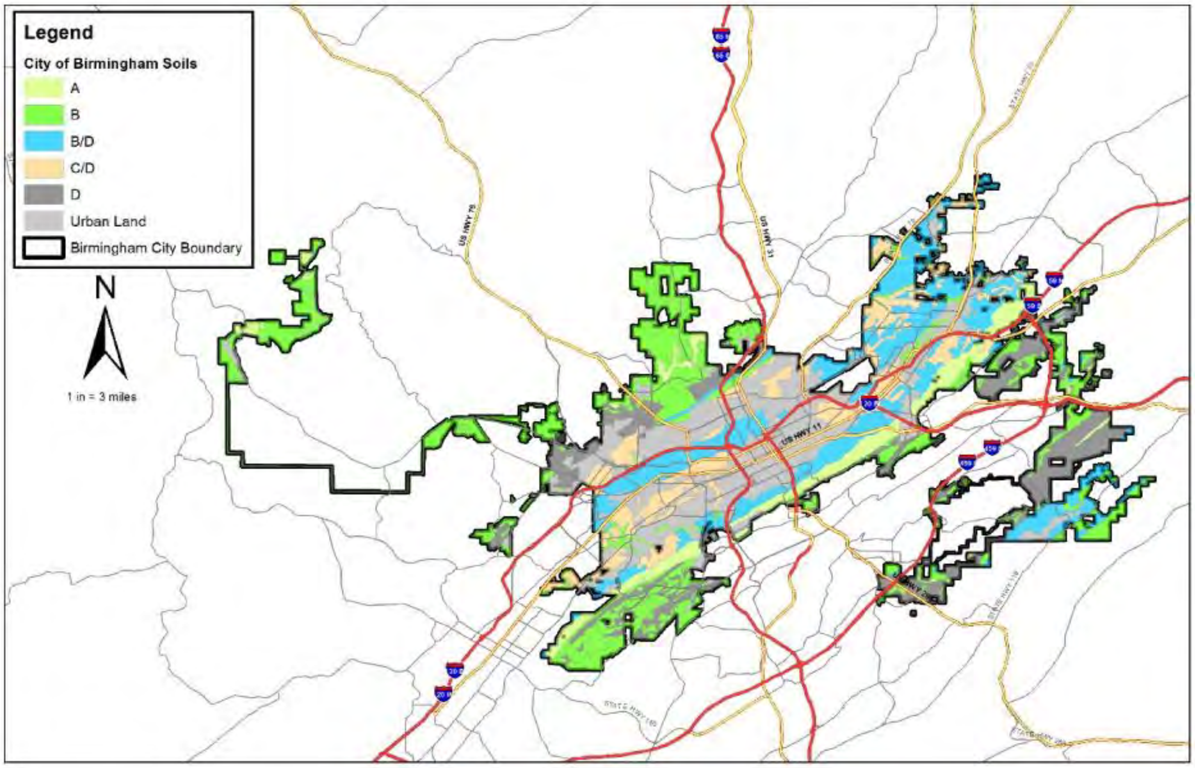
Designers should also consider construction access and staging during the design process. Activities that could compact soils where GIPs are sited should be avoided. Where site constraints make this unavoidable, the designer shall compensate accordingly in the design of the GIP. During construction, soils should not be compromised by compaction from construction equipment. Care should be taken to minimize soil compaction throughout the GIP and especially at the plane of infiltration so that infiltration rates of native soils are not impacted. Acceptable excavation methods at infiltration practices include hand labor with shovels or the use of an excavator such as a backhoe or trackhoe (located outside the perimeter or footprint of the practice). Heavy equipment should never be used over the footprint of existing or planned infiltration practices. Prior to site disturbance, the perimeter of the practice should be partitioned off with temporary fencing/tape to keep heavy equipment from crossing the perimeter throughout time of active construction. In cases where the GIP is sufficiently large that equipment must enter it, methods proposed to limit and restore compacted soil must be approved in advance. It should also be noted that infiltration rates may decrease over time due to settlement of filter media, compaction, or accumulation of sediment in the practice. To sustain infiltration rates long-term, it is important that a maintenance plan is in place. Regular maintenance should be conducted to optimize operating infiltration rates.

The United States Department of Agriculture (USDA) Web Soil Survey shall be used to identify soil map units and to make initial interpretations for potential uses and limitations of a site. However, since most soil map units have inclusions of other soils that may be quite different, detailed evaluations should be made at the proposed site by a professional soil scientist or soil classifier. A geotechnical report summarizing the soils information and results of infiltration testing, described in the next section, shall be submitted for all infiltration GIPs that do not utilize an underdrain. On-site evaluations should properly identify a soil or the hydrologic soil group (HSG), and the final decision for use should be made based on the detailed determination of soil series or HSG. See **Table E-1** for a list of HSG properties, and **Figure E-1** for a map of approximate HSG locations in Birmingham.

Table E-1. Description of HSG Properties *(Source: USDA and NRCS 2007)*

Hydrologic Soil Group	Properties
HSG A	Low runoff potential when thoroughly wet, less than 10 percent clay and more than 90 percent sand or gravel, and have sandy texture.
HSG B	Moderately low runoff potential when thoroughly wet, between 10 percent and 20 percent clay and 50 percent to 90 percent sand, and have loamy sand or sandy loam texture.
HSG C	Moderately high runoff potential when thoroughly wet, between 20 percent and 40 percent clay and less than 50 percent sand; and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures.
HSG D	High runoff potential when thoroughly wet, greater than 40 percent clay and less than 50 percent sand, and have clayey textures.

Figure E-1. Birmingham Map of HSGs



Infiltration GIPs perform best when sited in well-drained soils such as HSG A or B. The HSG and an infiltration test will determine if an infiltration GIP is a good fit for the soils on site. The need for underdrains is driven by permeability of the native soil. **<u>Native soils with an infiltration rate less than 0.5" per hour require underdrains to help drain effluent from the media</u>**.

The purpose of GIPs is to store, treat and infiltrate storm water into the soil, mimicking natural systems. Subsurface conditions are key in assessing the feasibility of infiltration in the design of GI. Infiltration capacity testing and design of GIPs that rely on infiltration to treat the storm water runoff shall follow the specifications summarized in this Section. While the Natural Resources Conservation Service (NRCS) soil classification of the site is encouraged as part of a desktop analysis to gain familiarity with potential native soil conditions, it is not adequate justification for infiltration testing results and cannot be substituted for infiltration testing using infiltrometers, test pits or other infiltration testing methods. A desktop analysis of soils data, topography, the location of streams, waterbodies, existing/previous land uses, and structures is encouraged to identify potential GIP locations and types. Existing or previous soil investigation or lab data may also be used to support preliminary siting of GIPs and infiltration testing. While NRCS soil classification of the site, described above, is encouraged as part of a desktop analysis to gain familiarity with potential native soil conditions, it is not adequate justification for infiltration testing results and cannot be substituted for infiltration testing using infiltrometers or test pits.

E.2 Infiltration Testing

An infiltration test shall be performed to determine the draw down time for the GIP location. An infiltration test is **NOT** required if the GIPs are designed with an underdrain. The location of each infiltration test shall correspond to the location of the proposed infiltration area. Infiltration testing shall be performed within an open test pit.

If a confining layer is encountered, it is recommended that the extent of the confining layer be determined via additional soil exploration. Although there is a short-term cost associated with over excavation and soil amendments, it may be a less expensive alternative when compared with the costs of operating and maintaining a failed infiltration GIP over the long term. Information on the use of soil amendments to improve the soil infiltration rate is included in **Appendix D**. Personnel conducting infiltration tests should be prepared to adjust test locations and depths depending on observed conditions.

Infiltration tests shall not be conducted in the rain or within 48 hours of significant rainfall events (greater than 0.5"), or when the temperature is below freezing. Infiltration testing performed; including testing procedures followed, shall be documented and submitted with the development plan. Infiltration testing shall be conducted by a qualified professional and plans including infiltration testing results must be certified by a professional engineer or professional geologist. Portions of this Appendix present testing methods at the bottom of an excavation. It is the testing personnel's responsibility to be aware of and take proper health and safety precautions for activities in an excavation. See the U.S. Occupational Health and Safety Administration (OSHA) for guidelines and requirements (www.osha.gov).

A tiered approach to infiltration testing recognizes the importance of accurate in situ conditions while screening out sites unsuitable for infiltration practices and thereby reducing soil investigation and testing costs. Tier 1 is the Feasibility Analysis. Tier 2 is the Conceptual Design Testing. If Tier 1 results show infiltration less than or equal to 0.5" per hour, then an underdrain is required. If Tier 1 results show infiltration greater than or equal to 0.5" per hour, then conceptual design testing is required under Tier 2 to demonstrate the infiltration rate. Minimum testing recommendations for each tier are summarized in **Table E-2** and described in more detail below.

Table E-2. Testing/Design Considerations *(Source: GSMM 2016)*

GIP Type	Tier 1: Feasibility Analysis	Tier 2: Conceptual Design Testing	
		For initial yields equal to or greater than 0.5"/hr	For initial yields less than 0.5"/hr
Linear practices	1 single-ring infiltrometer test per site	1 single-ring infiltrometer test and 1 test pit per 400 linear feet (minimum 1 infiltration test per test pit) of GIP	Underdrain required
Non-linear practices (bioretention areas, ponds, etc.)	1 single-ring infiltrometer test per site	1 single-ring infiltrometer test and 1 test pit per 400 square feet of practice area (minimum 1 infiltration test per test pit)	Underdrain required

E.3 Single-Ring Infiltrometer Test

For a Tier 1 feasibility analysis, a minimum of one single-ring infiltrometer test must initially be performed on site. This test method utilizes perforated 200 mm to 250 mm (8" to 10") plastic or metal canisters with bottom, set in coarse drainage sand, to minimize disturbance to in-place soils and to prevent siltation of the test hole during testing.

1. Holes in the test canister should be 3 mm (1/8") diameter and spaced on 25 mm (1") centers.
2. Excavate a test hole to the depth of the infiltration plane, or the bottom of the GIP and approximately 25 mm (1 inch) larger diameter and approximately 25 mm (1 inch deeper than the

dimensions of a test canister. If the depth of testing is greater than 18", it may be necessary to excavate a shallow test pit to conduct testing.

3. Check that the sides of the test hole are not smooth, but scarified.
4. Place coarse drainage sand in the bottom of the hole and place the canister firmly into the hole. The bottom of the hole should be uncompacted.
5. Backfill the space around the canister with soil and tamp the soil into place.
6. Fill canister with water and allow to drain completely or to soak the surrounding soils for a minimum of one hour, whichever occurs first. Re-fill the canister and measure the rate at which the water level drops.
7. Record the infiltration rate as the decrease in depth of water per hour (inches/hour).

Where the feasibility analysis does not meet minimum infiltration criteria (0.5"/hr), the designer may prefer the use of an underdrain rather than continue with further testing. Where the feasibility analysis meets the minimum infiltration criteria 0.5"/hr), test pit infiltration tests are necessary for conducting infiltration testing per **Table E-2** to further verify site information characteristics.

E.4 Test Pit Infiltration Test

This test method consists of a trench or pit that allows visual observation of the soil horizons and overall soil conditions at a particular location on the site. Multiple test pit observations can be made for a relatively low cost and in a short time period. The use of soil borings shall not be substituted for test pits. Test pits allow in-situ visual observation of soil conditions, where soil borings do not. Soil borings are encouraged to supplement data collection but cannot be substituted for infiltrometer or test pits.

1. Dig a backhoe-excavated trench/pit, 2.5 to 3 feet wide, to the proposed depth of the infiltration plane of the practice, or until bedrock or fully saturated conditions are encountered. Safe test pit entry should always be observed. A test pit should never be accessed if it is not safe to do so. OSHA regulations should always be observed.
2. Document soil profile (soil horizons, soil texture and color and depth below ground surface, depth to water table, depth to bedrock, etc.).
3. Based on observed field conditions, the qualified professional should consider modifying the proposed infiltration plane of the practice and adjust infiltration testing locations as necessary.
4. Perform Single-Ring Infiltrometer test (above) at depth of infiltration plane of proposed practice.
5. Soil samples may be collected at various horizons for additional analysis at the designer's discretion.
6. After testing is complete, re-fill test pit with original native soils and stake the location of the test pit.

References

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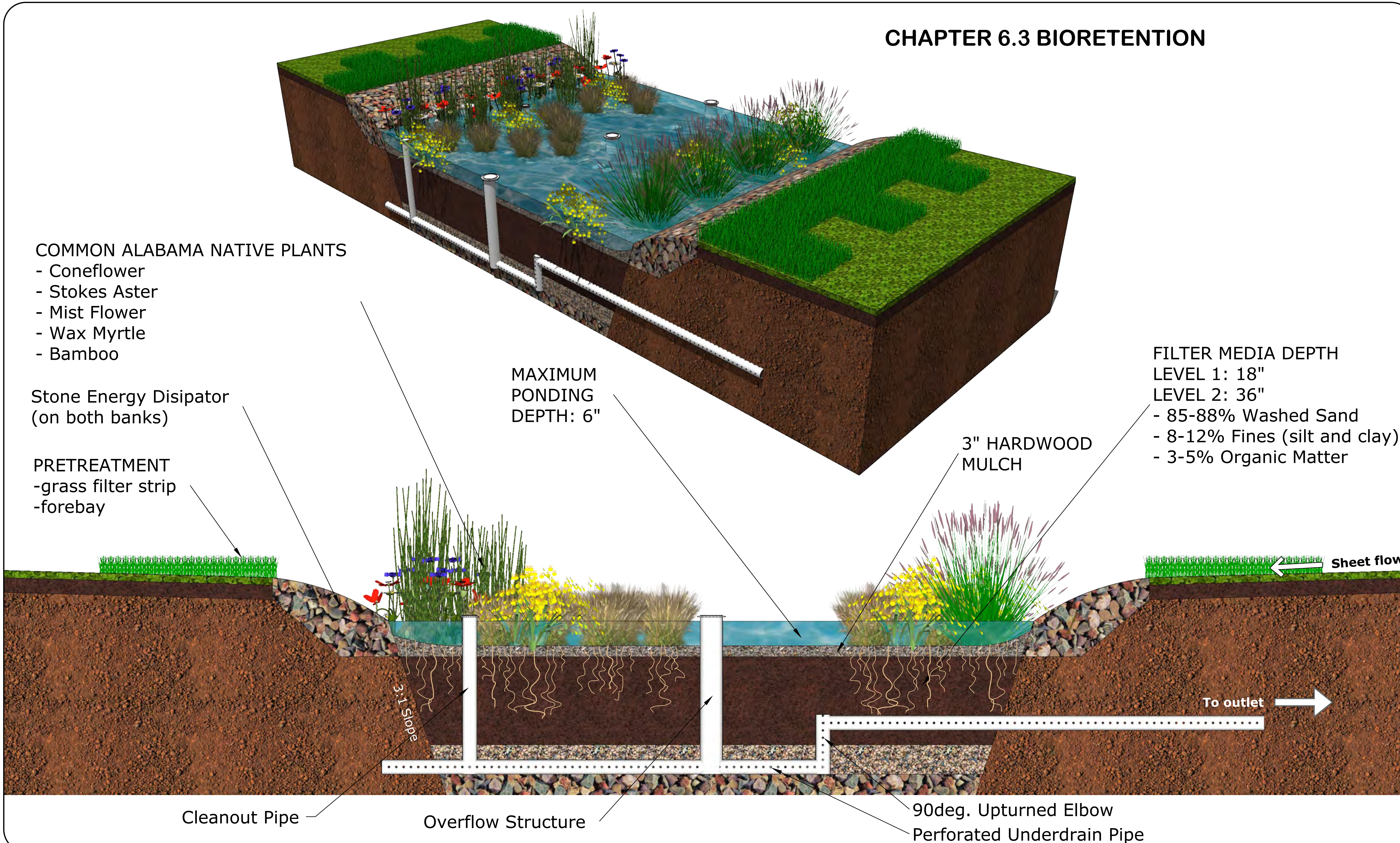
Appendix F
Typical Details for GIPs and BMPs

CHAPTER 6.3 BIORETENTION



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CHAPTER 6.3 BIORETENTION

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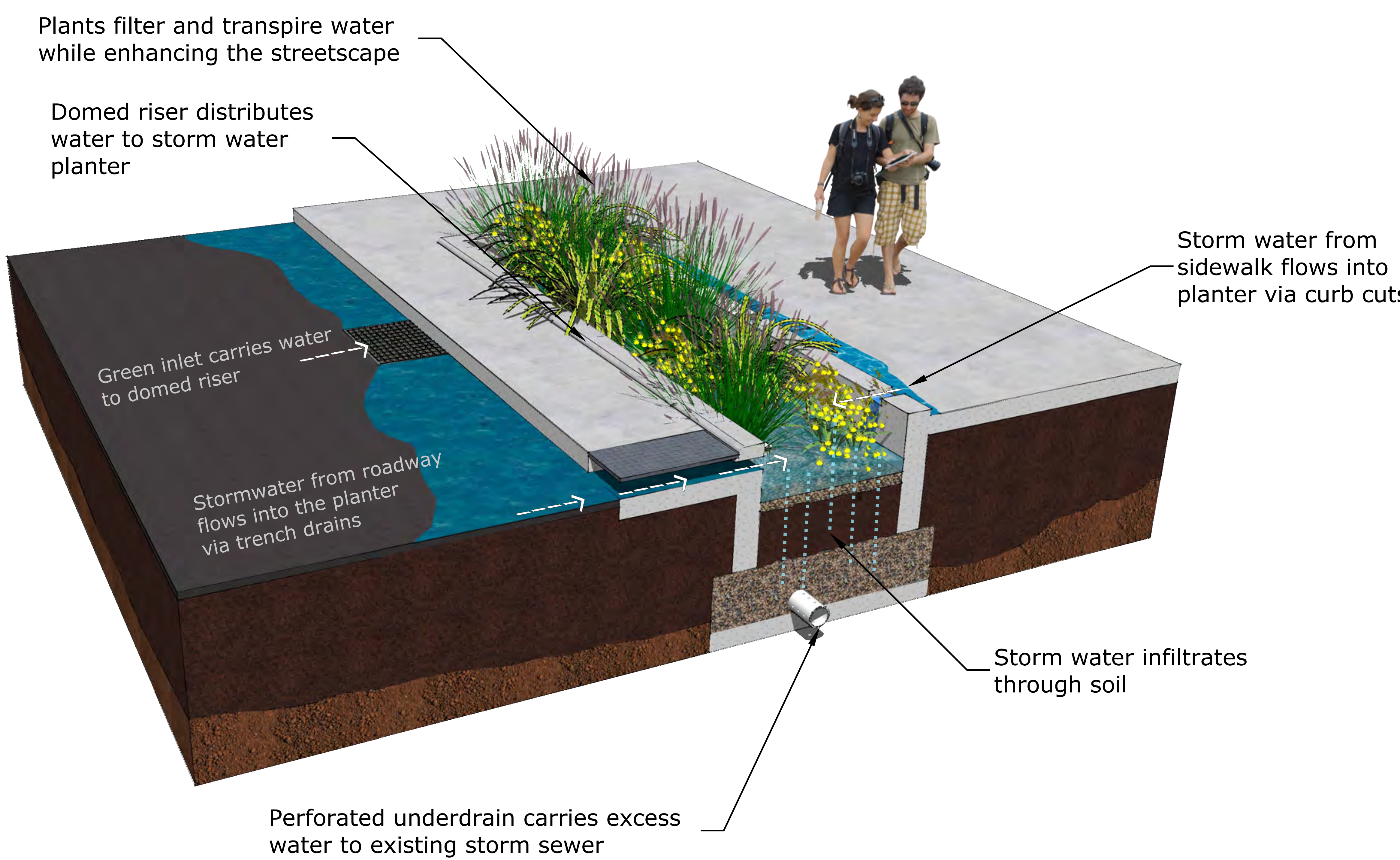
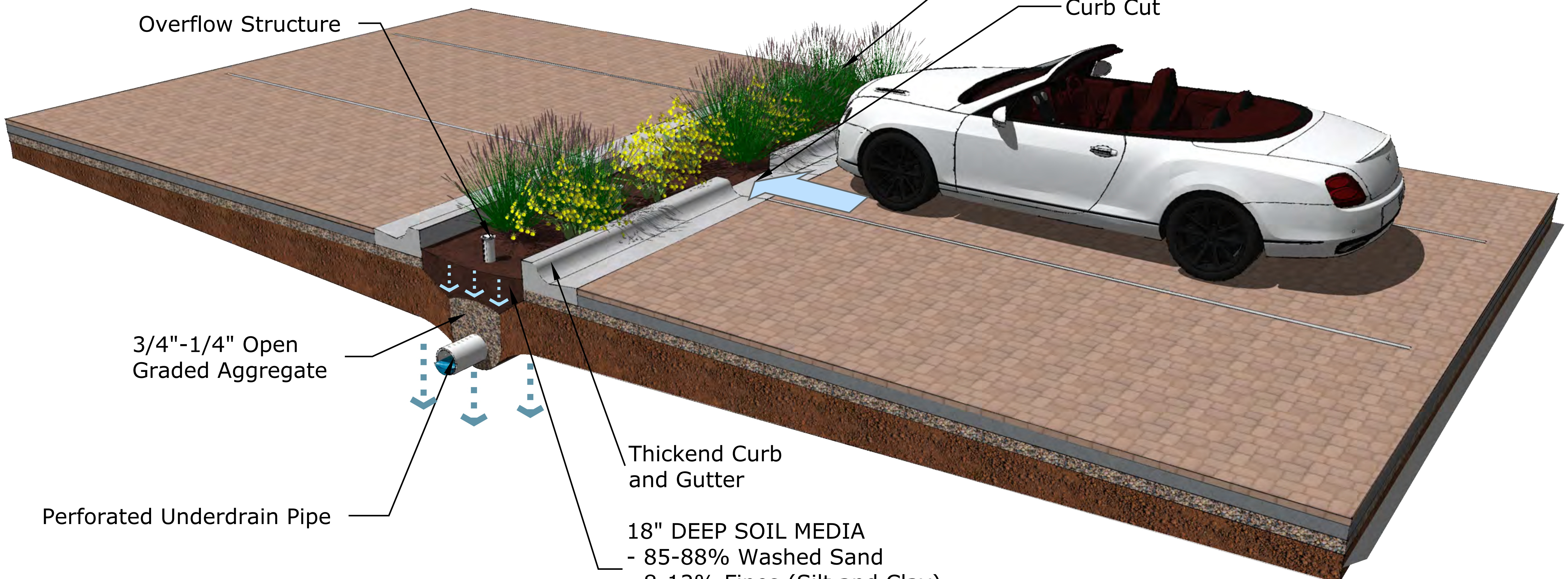
1 of 1

CHAPTER 6.4 URBAN BIORETENTION



CHAPTER 6.4 URBAN BIORETENTION



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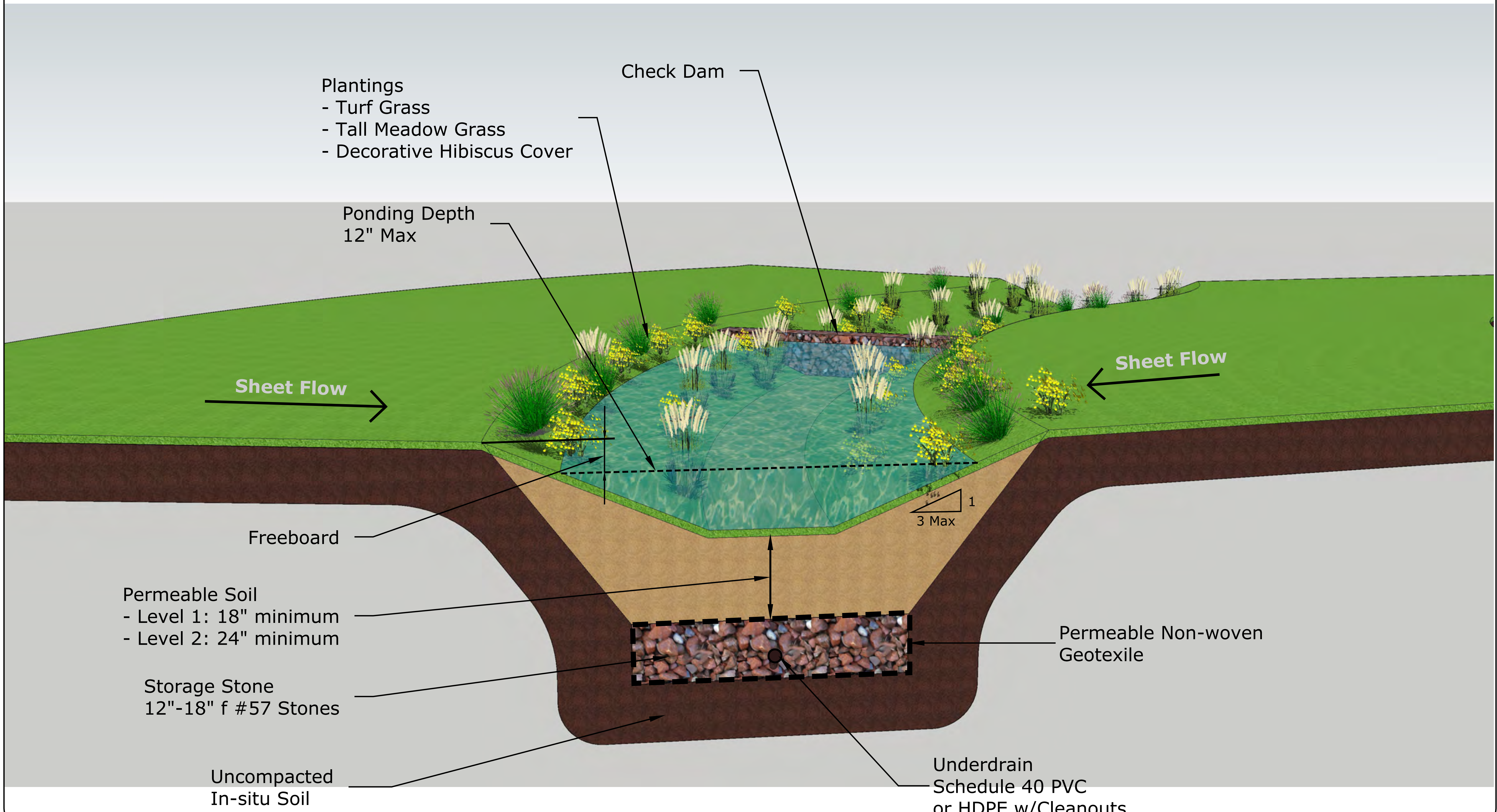
CHAPTER 6.5 DRY WATER QUALITY SWALE / ENHANCED SWALE



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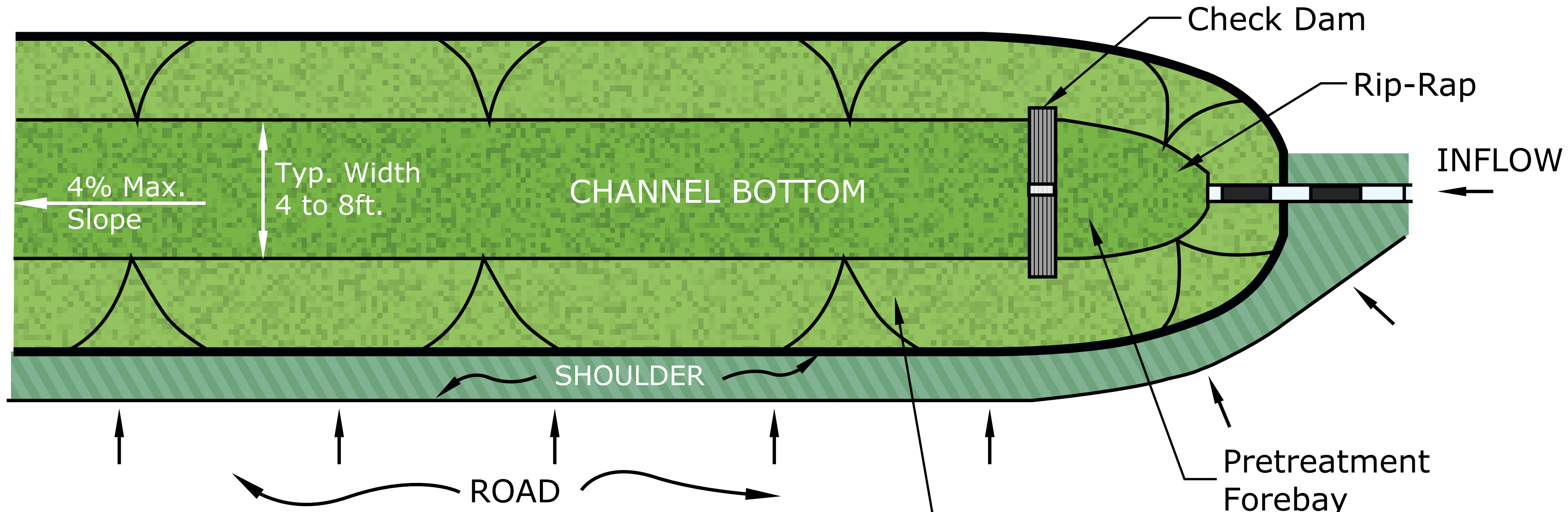
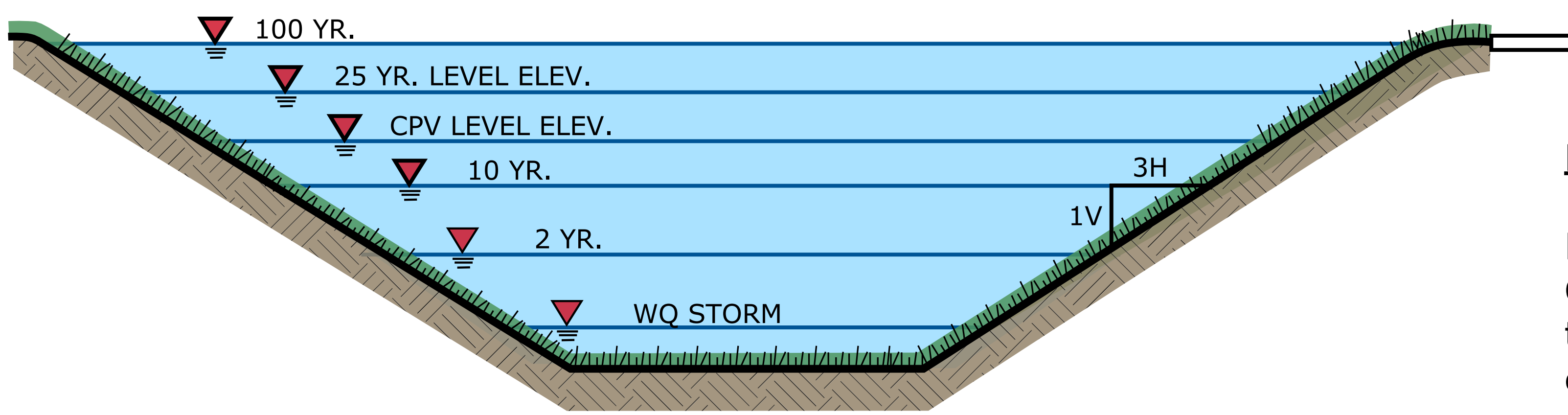
CHAPTER 6.7 GRASS CHANNEL / OPEN CHANNEL



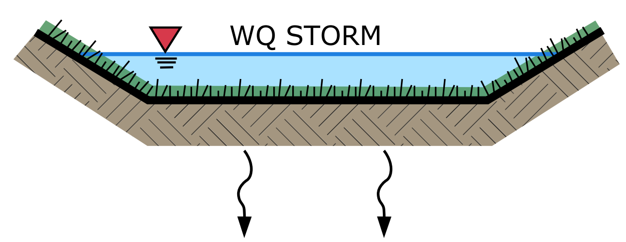
PLAN



PROFILE

NOTE:

Dimension of the Channel should ensure that flow velocity is non erosive for 2 and 10 yr design storm. 10 yr design storm shall be contained in the channel - minimum 6" free board.



LIMITED INFILTRATION

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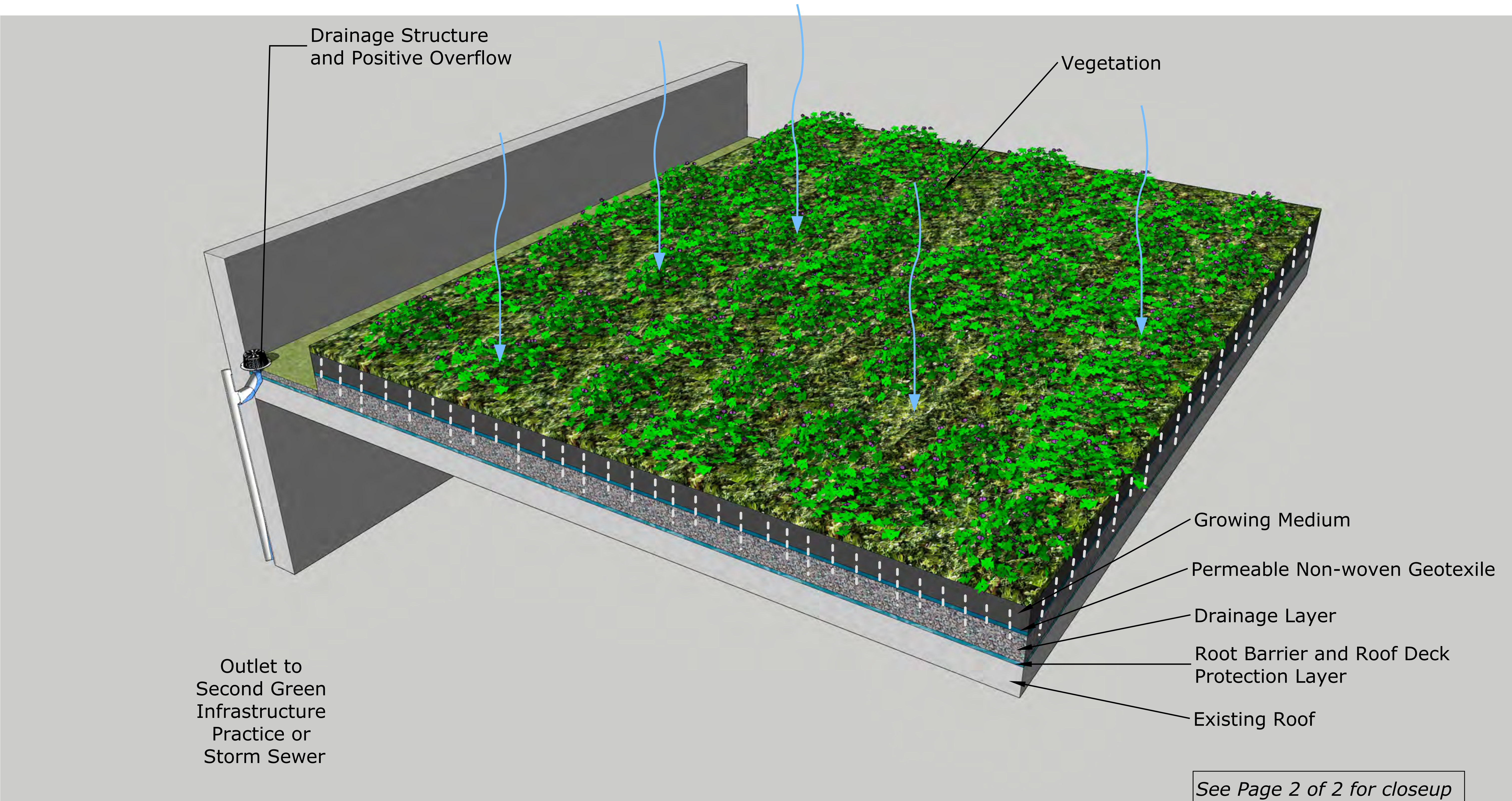
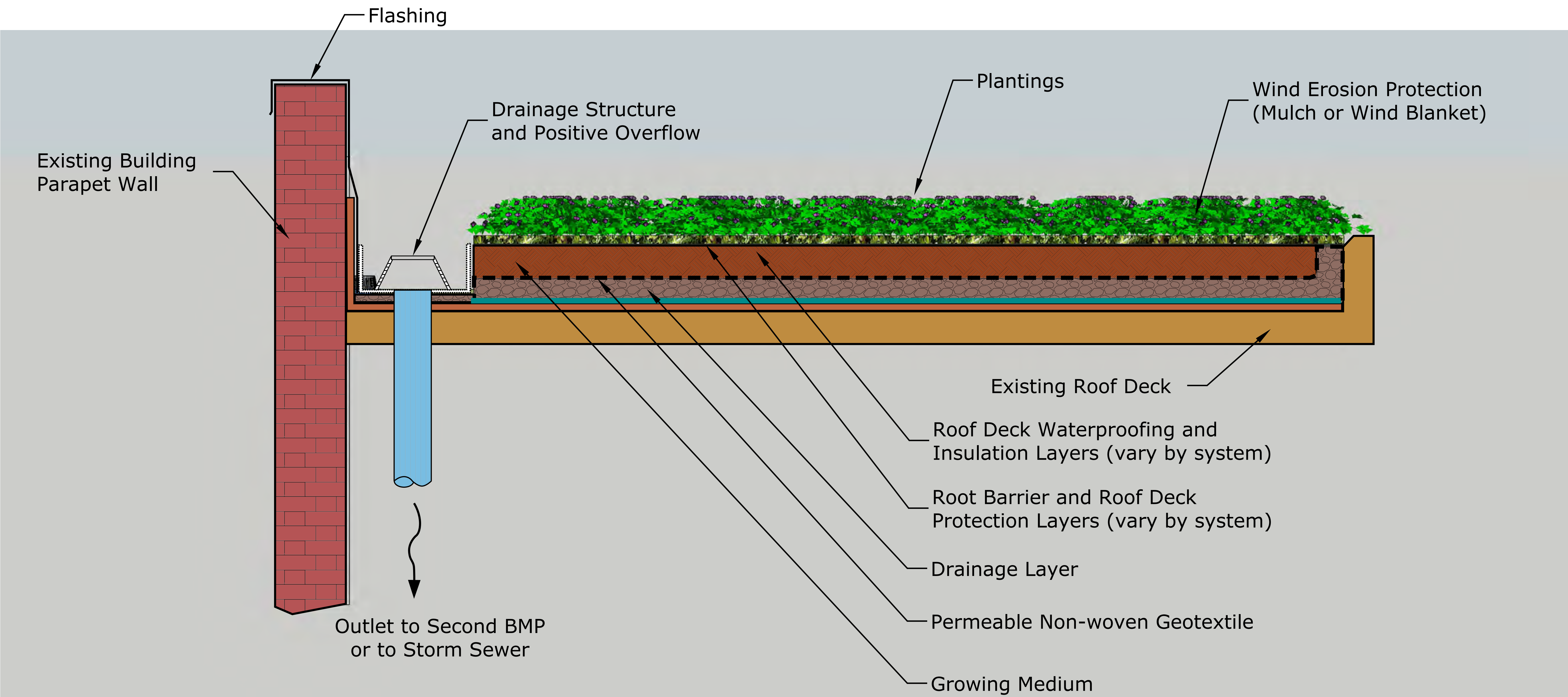
CHAPTER 6.10 GREEN ROOF



See Page 2 of 2 for closeup of Cross Section

CHAPTER 6.10 GREEN ROOF

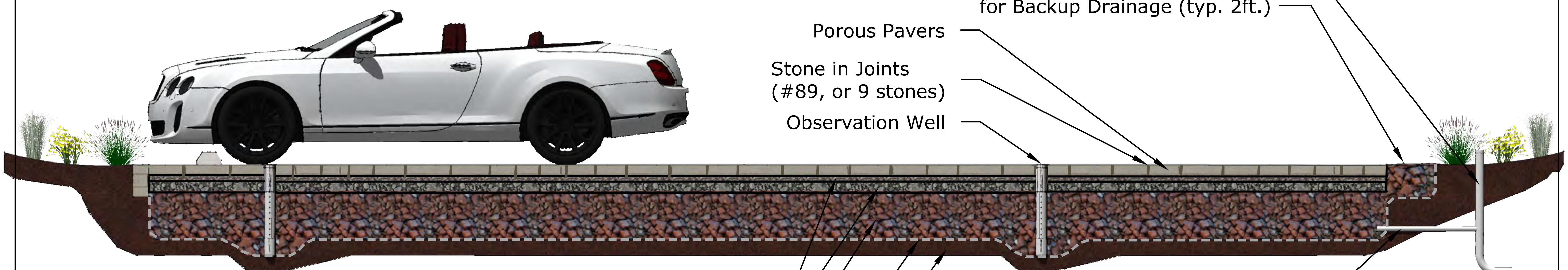


CHAPTER 6.11 PERMEABLE PAVEMENT

NOTES:

Level 1 Design: Underdrain required

Level 2 Design: Underdrain not required; or if an Underdrain is used, a 12" stone sump shall be provided below the Underdrain invert.



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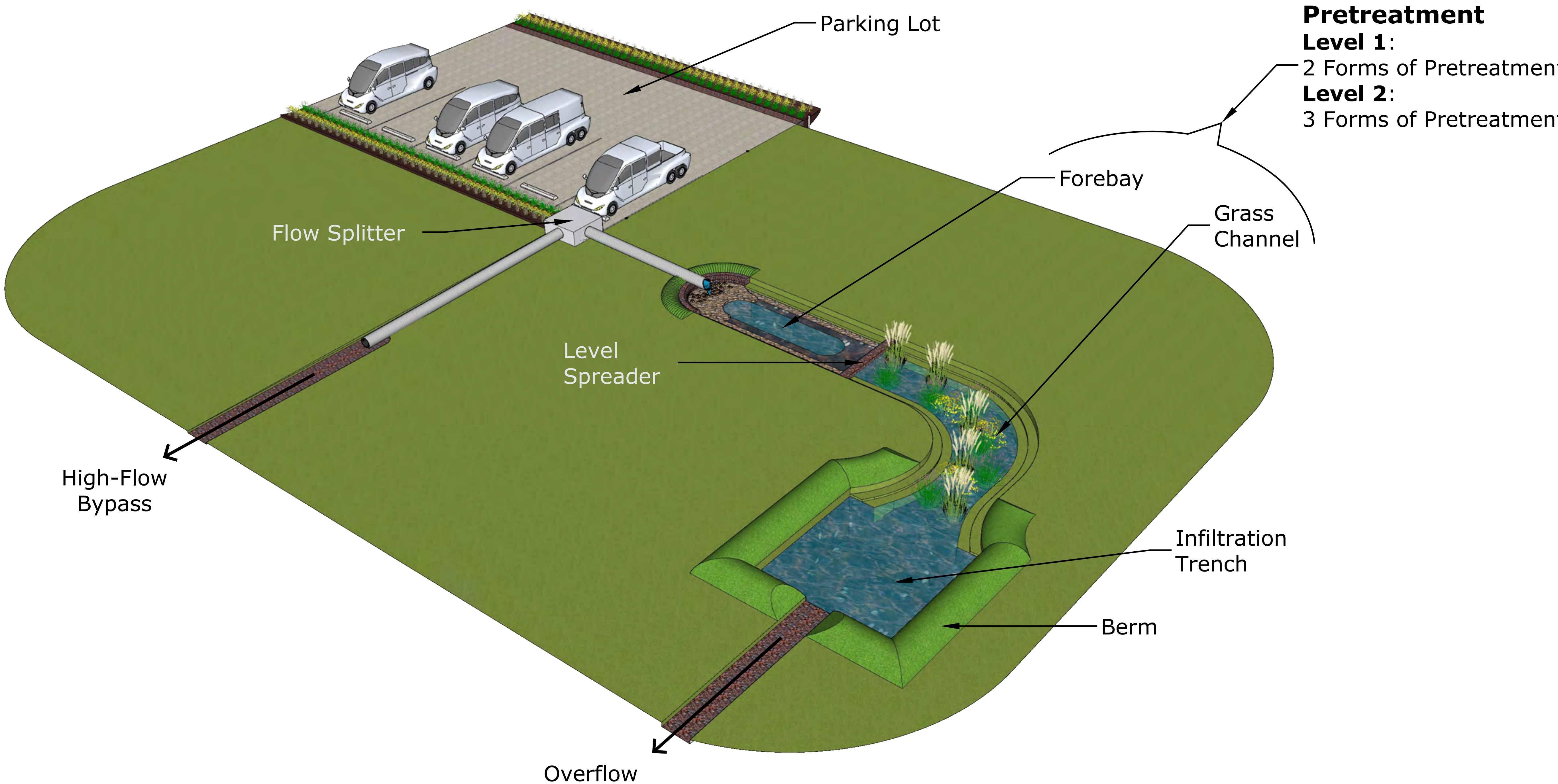
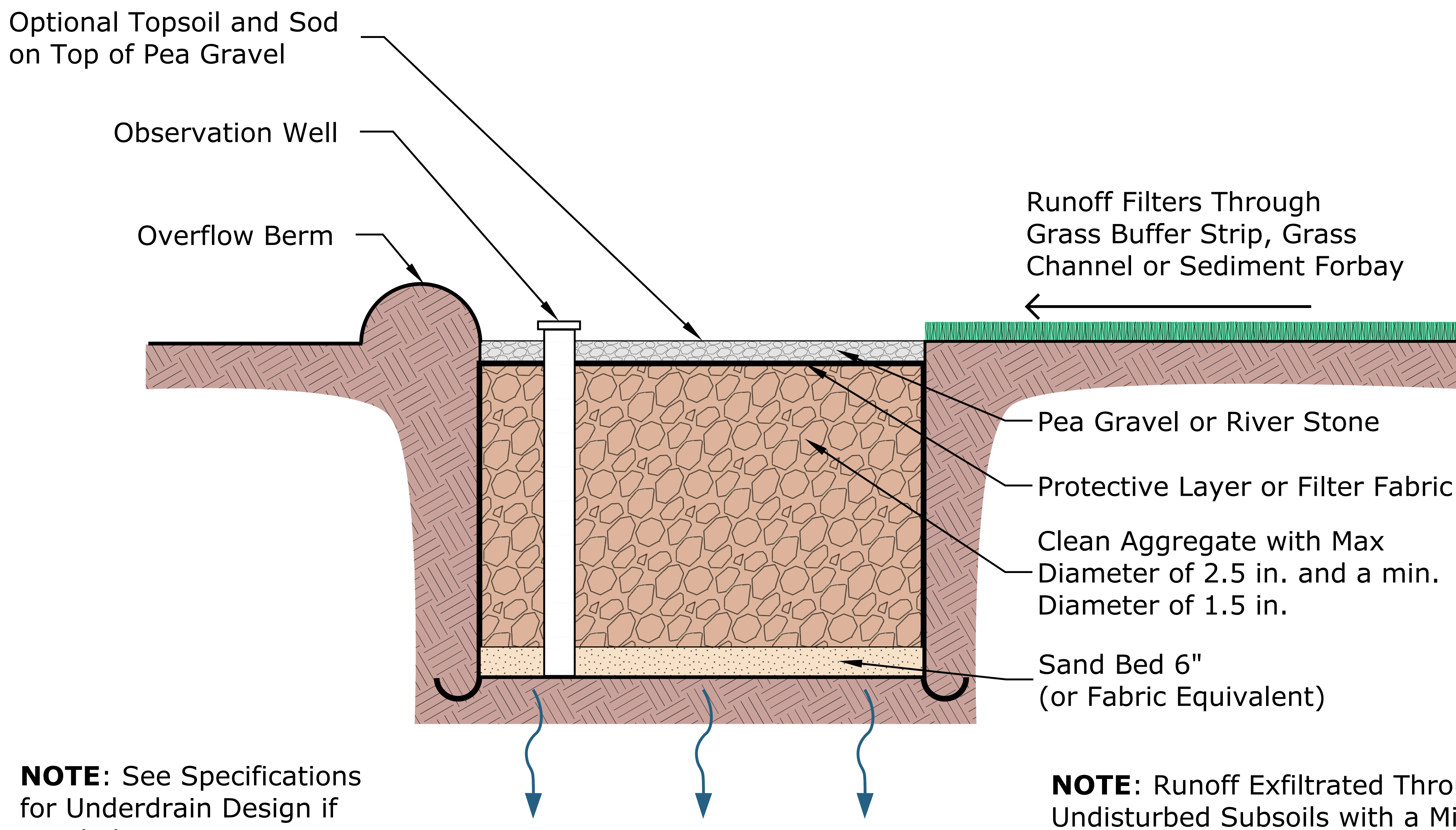
CHAPTER 6.12 INFILTRATION TRENCH



CHAPTER 6.12 INFILTRATION TRENCH SECTION



NOTE: See Specifications for Underdrain Design if Needed

NOTE: Runoff Exfiltrated Through Undisturbed Subsoils with a Min Rate of 0.5 Inches Per Hour and the Following:

LEVEL 1:
>0.5 in/hr.
&
<1 in/hr.

LEVEL 2:
1 to
4 in/hr.

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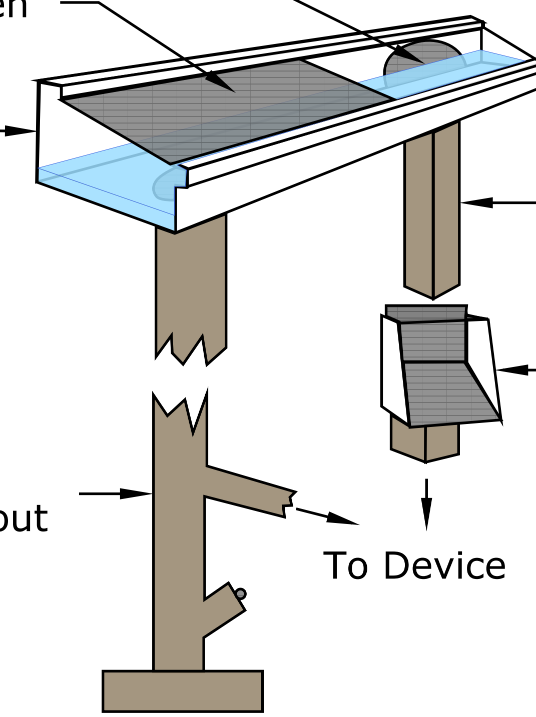
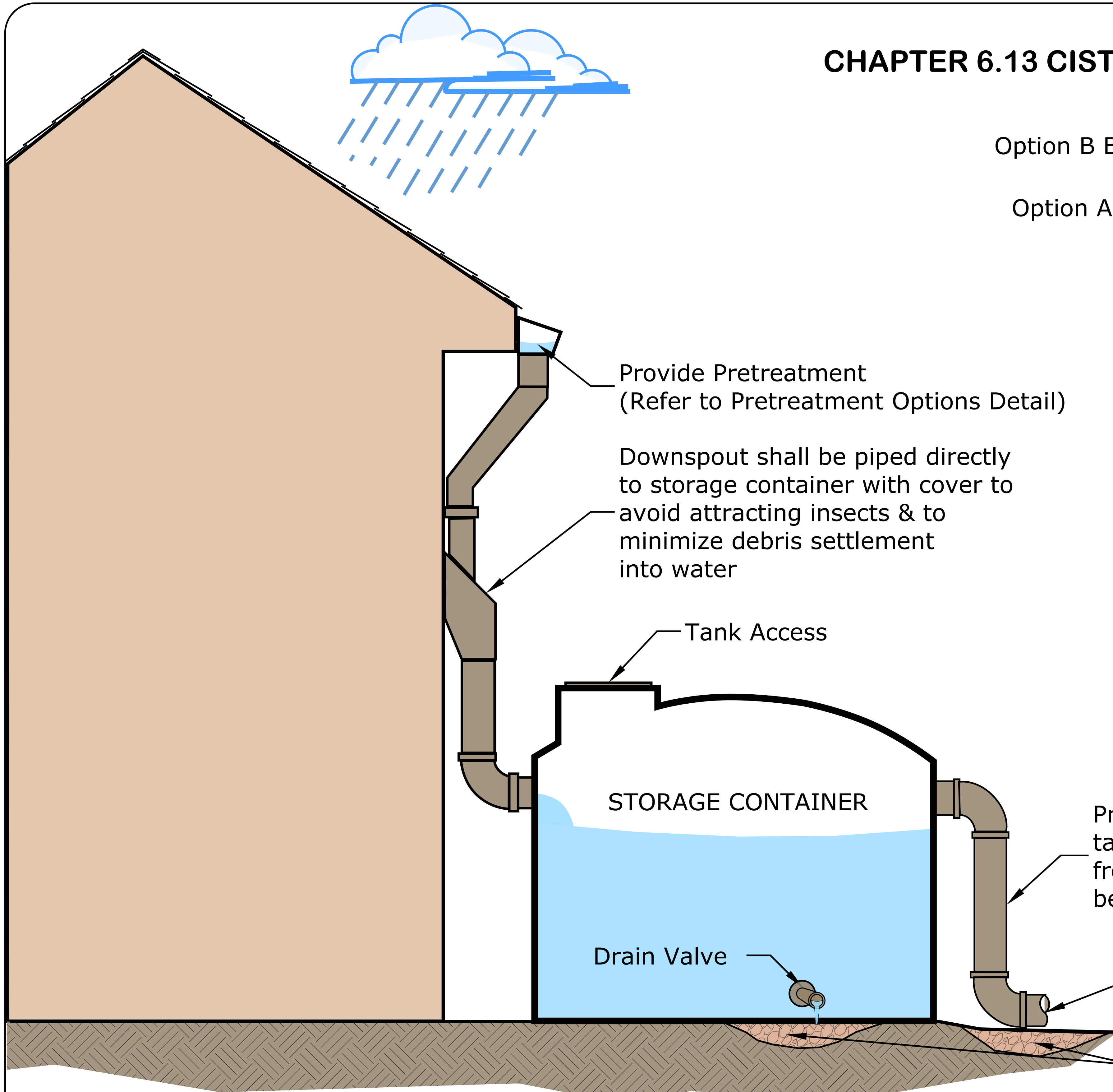
CHAPTER 6.13 CISTERN



NOTE:
Not all options are applicable to all devices.

PRETREATMENT OPTIONS DETAIL



NOTE:
The size of rain barrels and cisterns vary. Comply with all applicable Local and State Standards.

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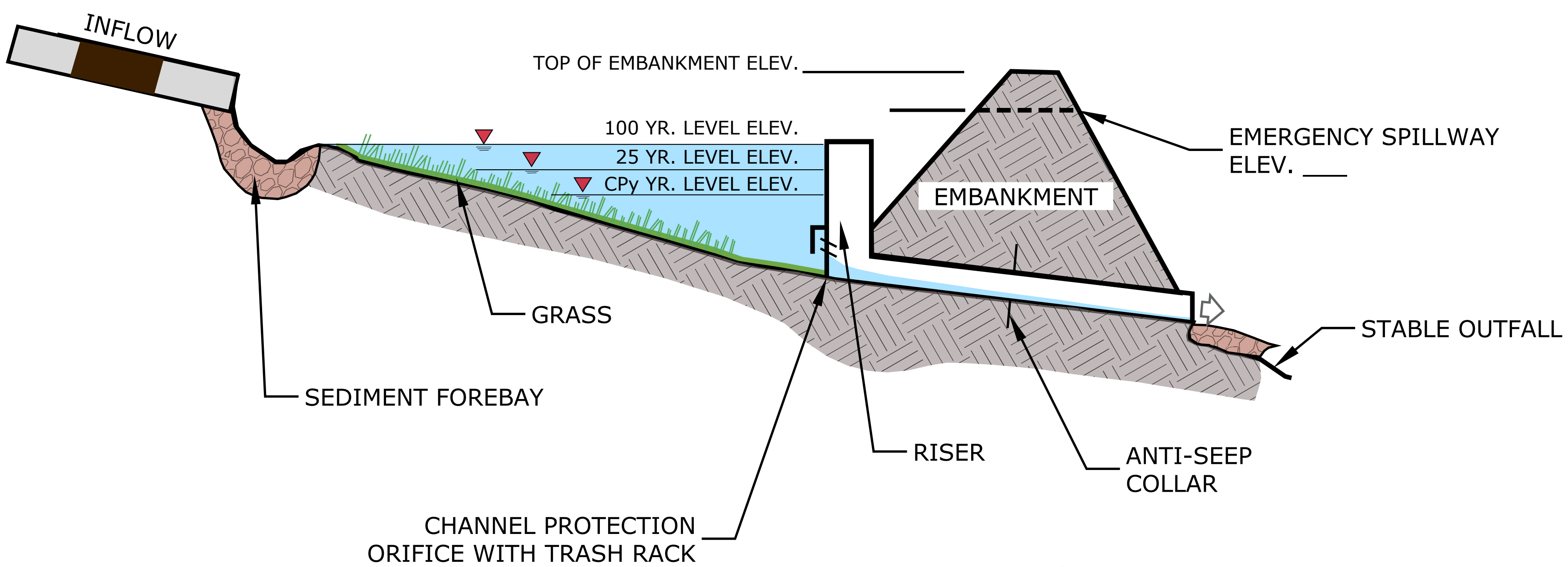
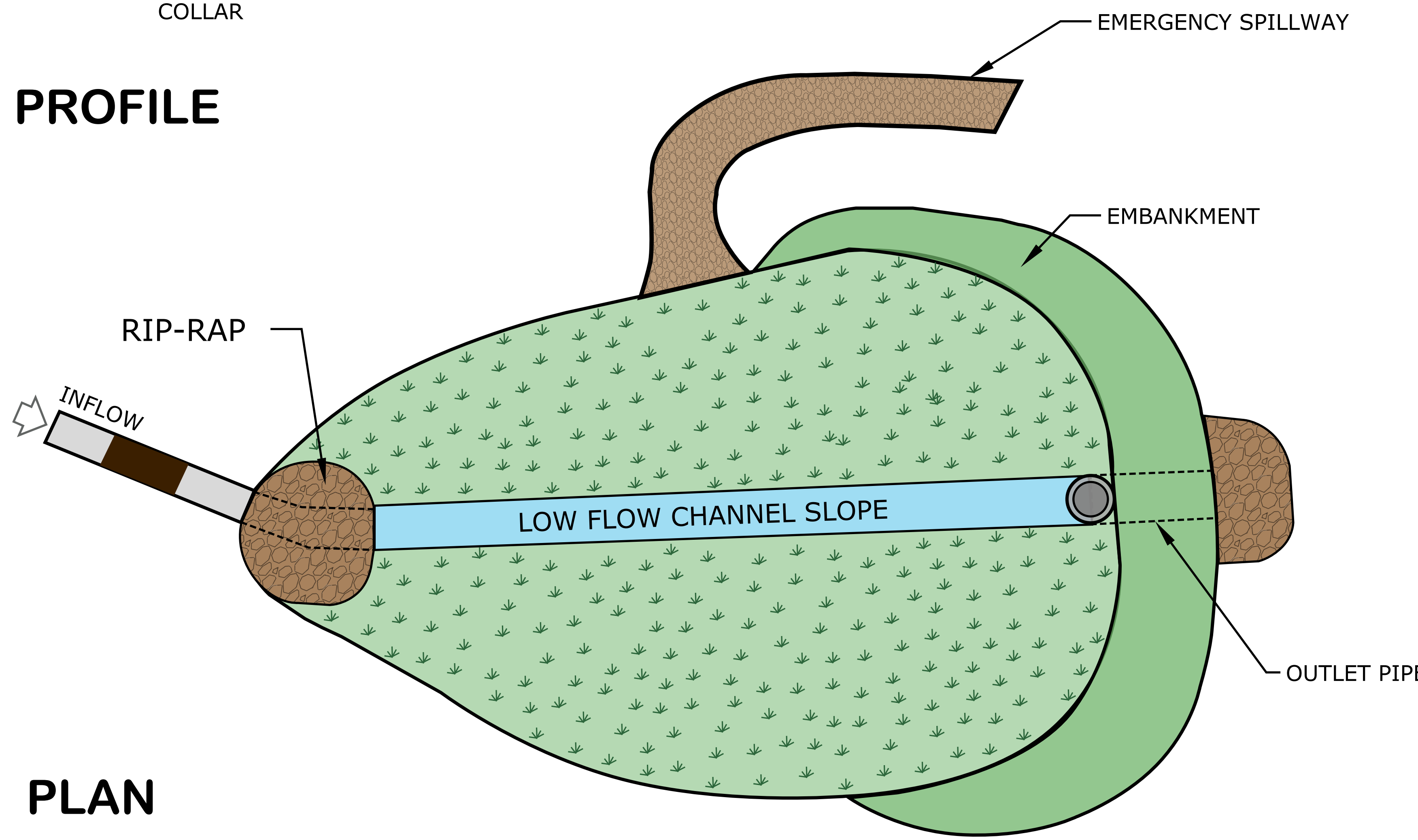
CHAPTER 6.14 DRY DETENTION POND / EXTENDED DRY DETENTION POND



PROFILE

NOTES:

1. PROVIDE A MINIMUM OF 1.0" OF FREEBOARD BETWEEN EMERGENCY SPILLWAY AND TOP OF EMBANKMENT.
2. PROVIDE A MINIMUM OF 0.1" BETWEEN 100 YR. LEVEL AND EMERGENCY SPILLWAY.



PLAN

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CHAPTER 6.14 DRY DETENTION POND / EXTENDED DRY DETENTION POND

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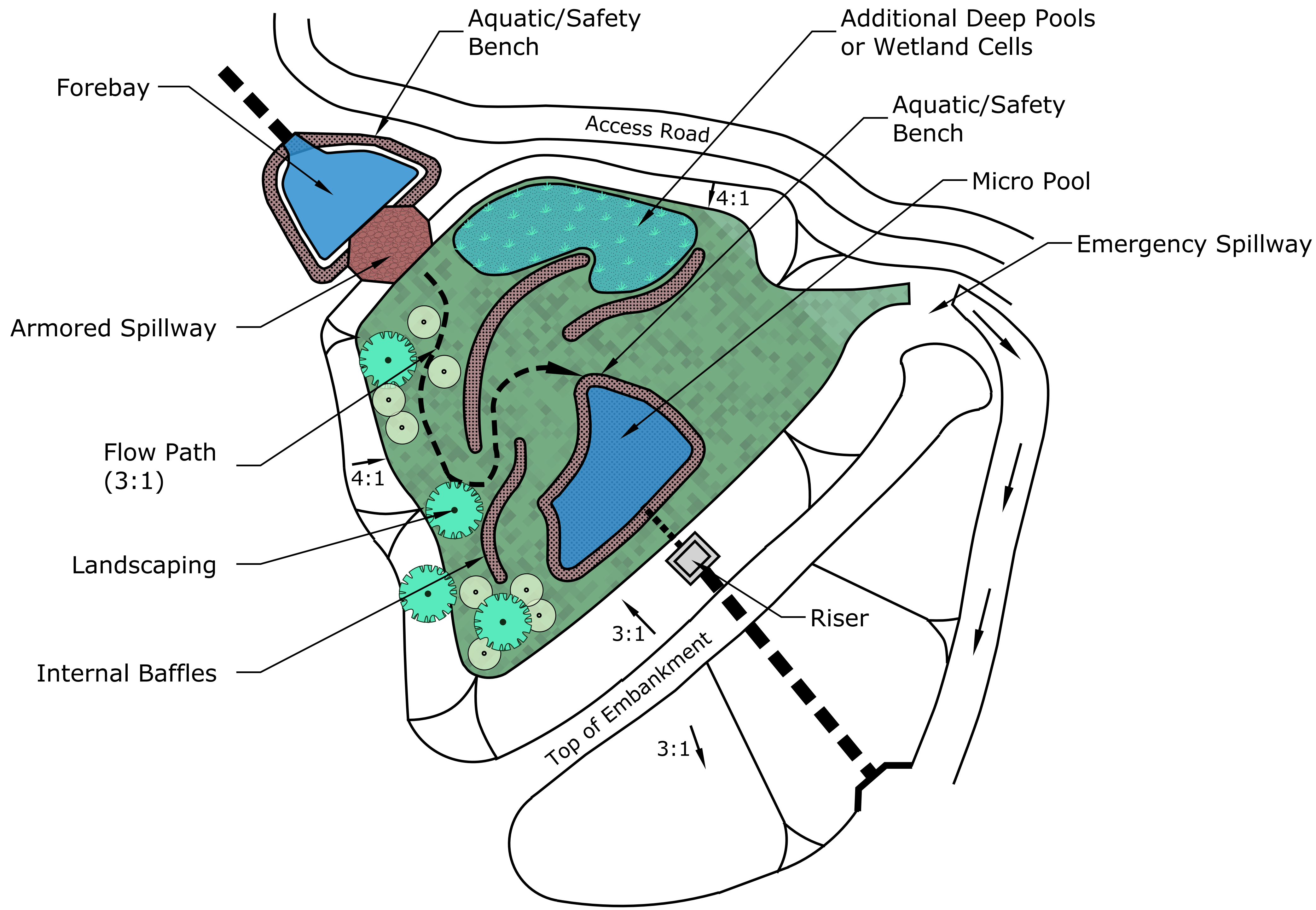
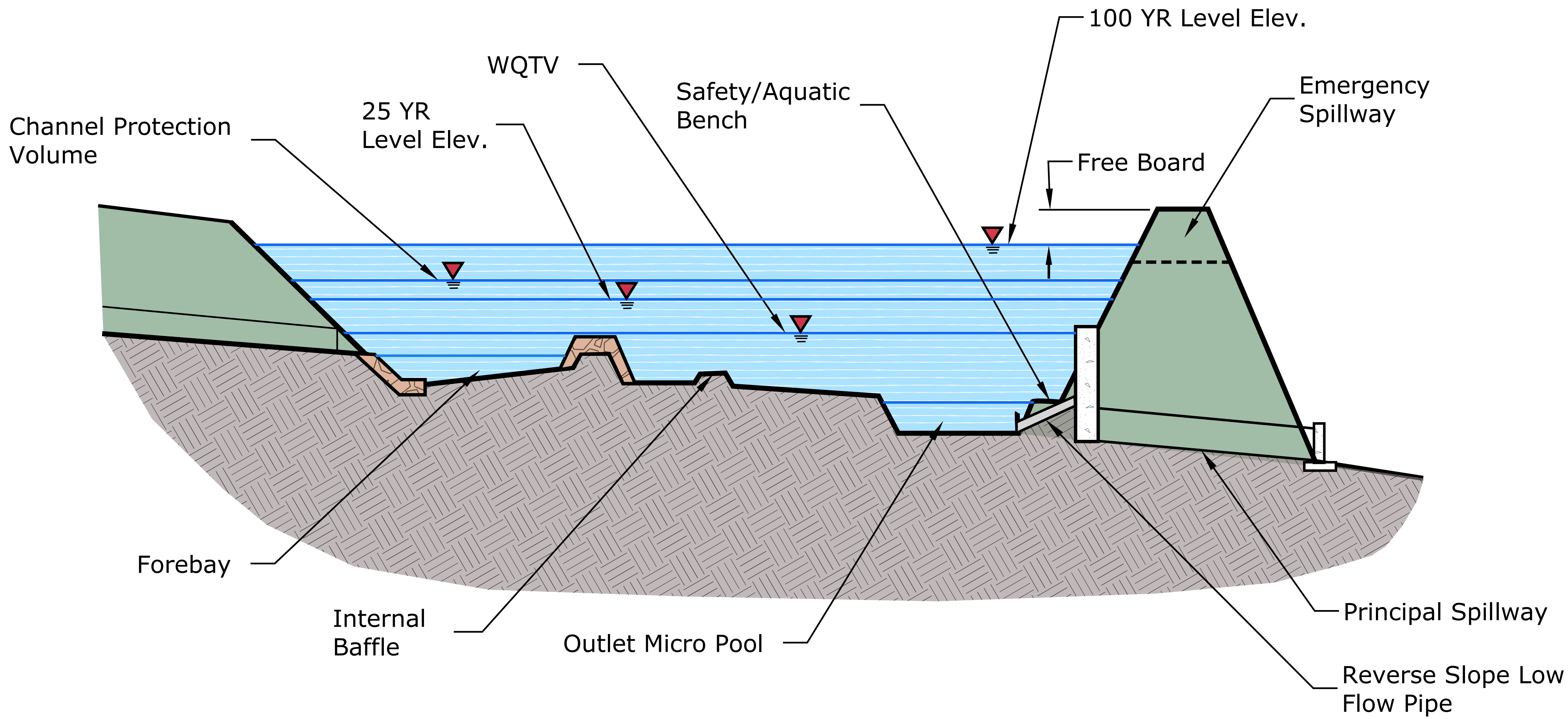
CHAPTER 6.15 EXTENDED DETENTION POND / STORM WATER WET POND

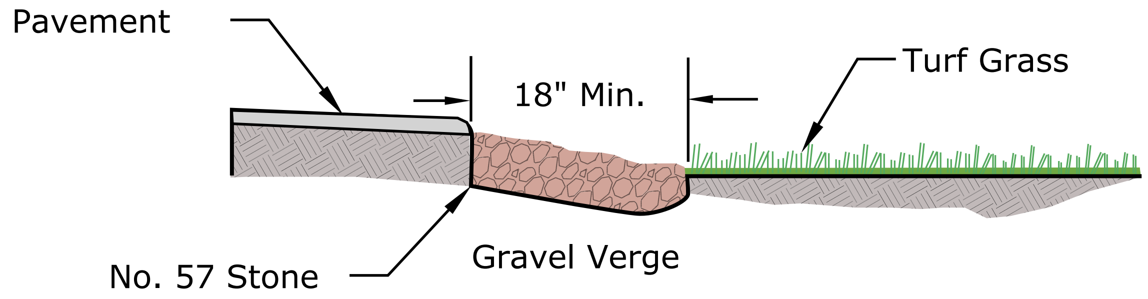


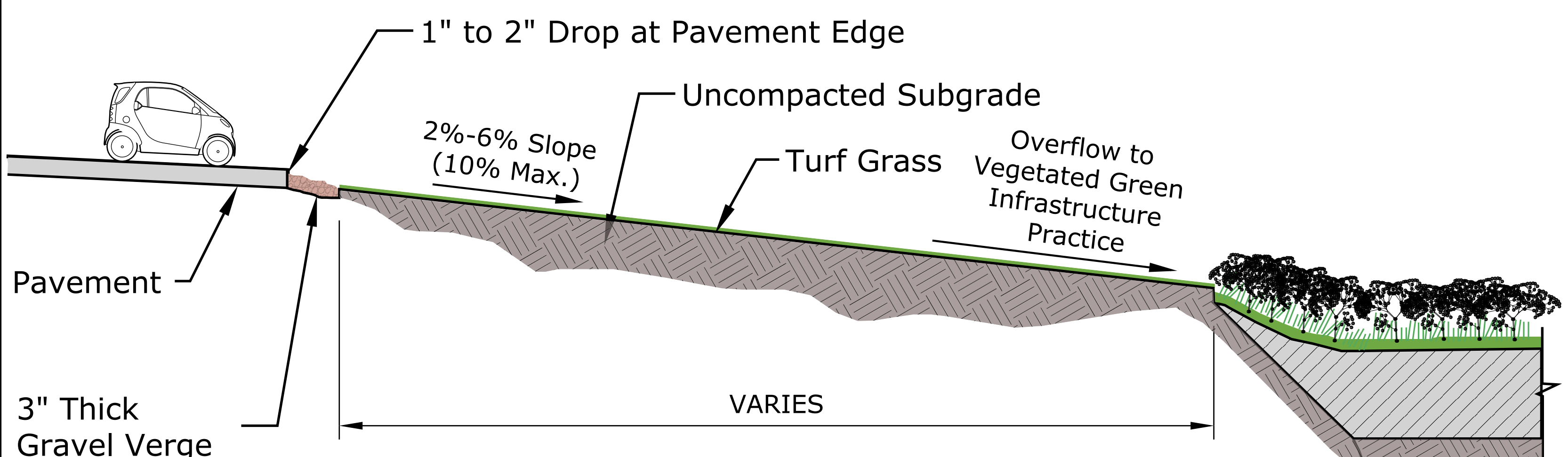
CHAPTER 6.15 EXTENDED DETENTION POND / STORM WATER WET POND



CHAPTER 6.6 DOWNSPOUT DISCONNECTION

GRASS FILTER STRIP





FILTER STRIP NOTES:

1. THE MAIN GOAL OF PRETREATMENT IS TO CAPTURE FLOATABLES, DEBRIS, GREASE, OILS, SILT AND SEDIMENT WHERE THEY CAN BE EASILY CLEANED AT THE SURFACE OF THE G1 PRACTICE THROUGH REGULAR MAINTENANCE, AND BEFORE THEY HAVE THE OPPORTUNITY TO CLOG THE PRACTICE.
2. FILTER STRIPS CAN BE USED EFFECTIVELY AS PRETREATMENT MEASURES AND CAN PROVIDE ENERGY DISSIPATION WITH THE ADDITION OF A LEVEL SPREADER, CHECK DAMS OR A GRAVEL VERGE.
3. ENSURE THAT FLOWS IN EXCESS OF THE DESIGN FLOW CAN MOVE ACROSS AND AROUND THE FILTER STRIP WITHOUT DAMAGE.
4. THE SLOPE OF THE FILTER STRIP SHOULD BE BETWEEN 2% AND 6% FOR OPTIMUM PERFORMANCE.
5. THE SLOPE OF THE FILTER STRIP SHALL NOT EXCEED 10%.
6. THE WIDTH OF THE FILTER STRIP SHALL BE 10 FEET MINIMUM OR EQUAL TO THE WIDTH OF THE RECEIVING G1 PRACTICE, WHICHEVER IS GREATER.
7. ALL DISTURBED AREAS SHALL BE IMMEDIATELY STABILIZED AFTER CONSTRUCTION TO MINIMIZE EROSION.
8. WIDTH OF GRASS FILTER STRIP VARIES; TO BE SPECIFIED BY PROJECT DESIGNER.
9. GRAVEL VERGE SHALL CONSIST OF NO. 57 STONE. WIDTH OF VERGE SHALL BE 18" MINIMUM AND DEPTH SHALL BE 3".

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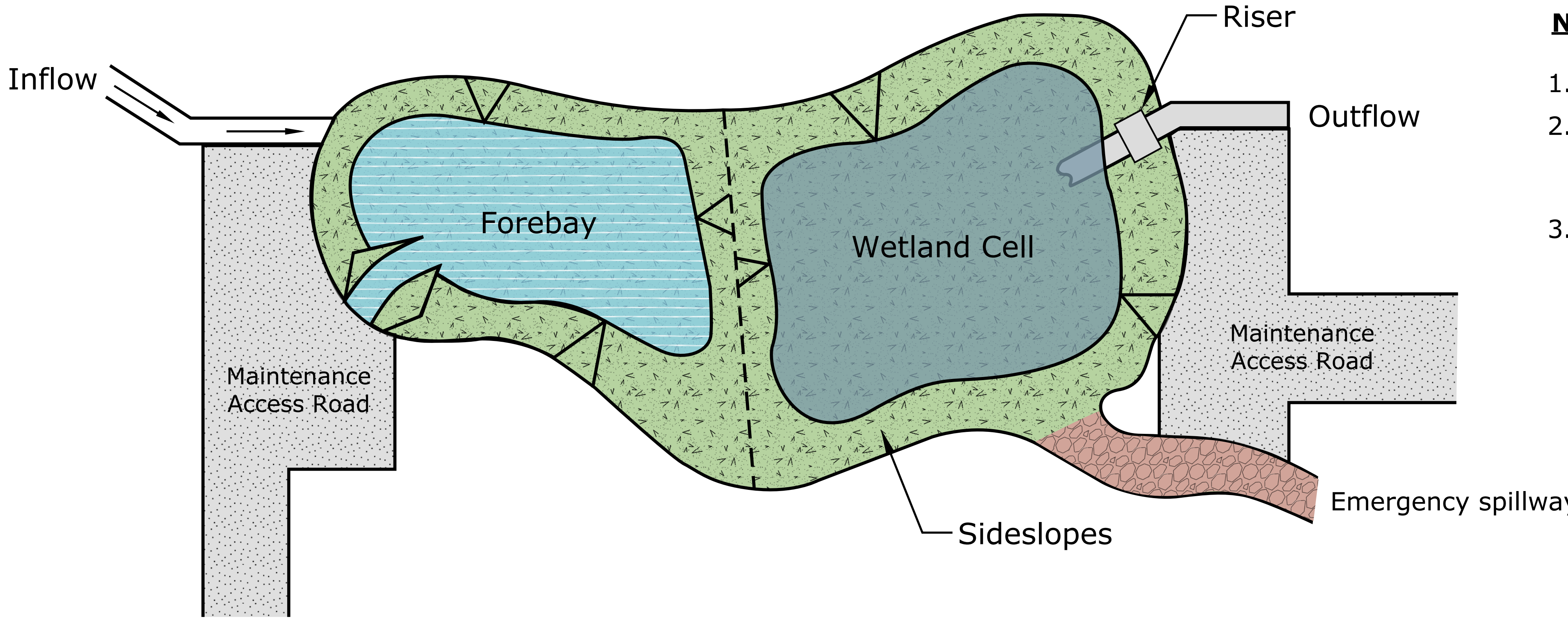
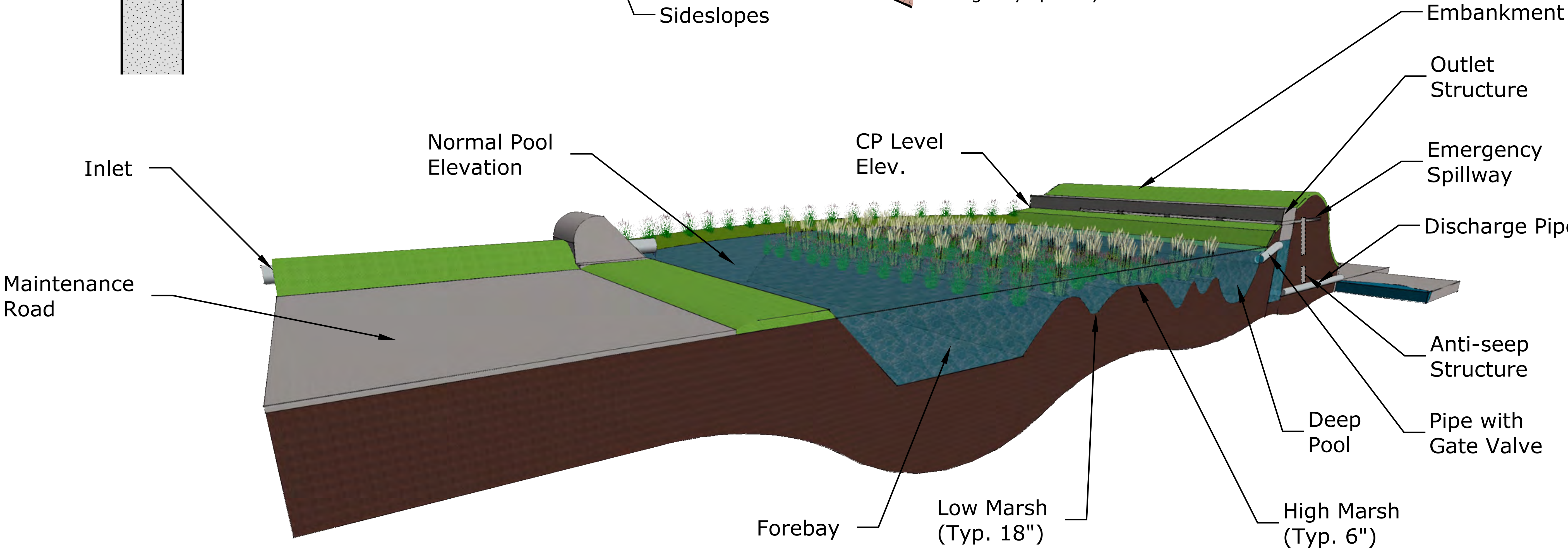
CHAPTER 6.16 STORM WATER WETLAND



NOTES TO DESIGNERS:

1. FOREBAY SHOULD BE AT LEAST 10% OF THE WQ.
2. PROVIDE A MINIMUM OF 1.0" OF FREEBOARD BETWEEN EMERGENCY SPILLWAY AND TOP OF EMBANKMENT.
3. PROVIDE A MINIMUM OF 0.1" BETWEEN 100 YR. LEVEL AND EMERGENCY SPILLWAY.



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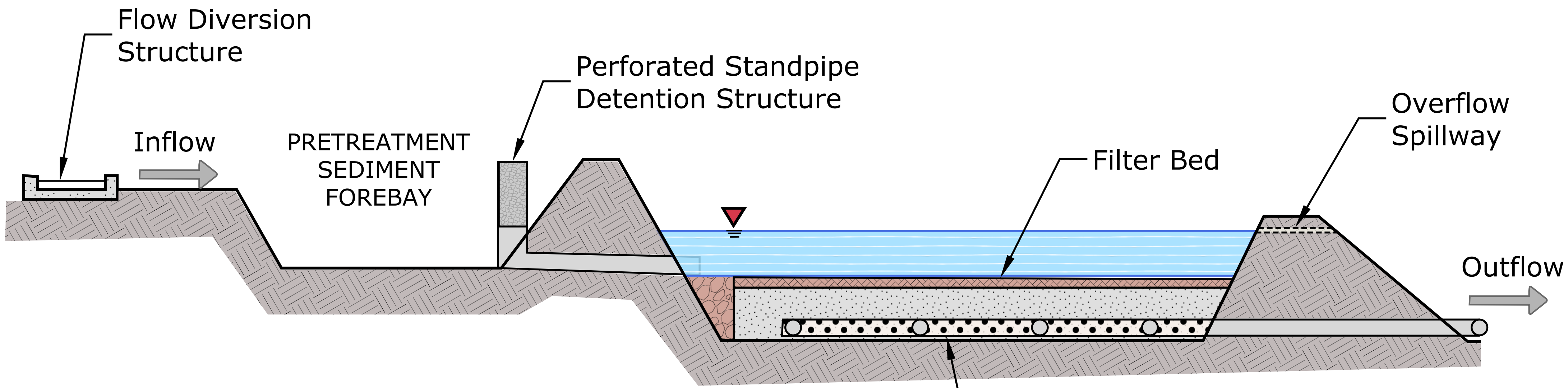
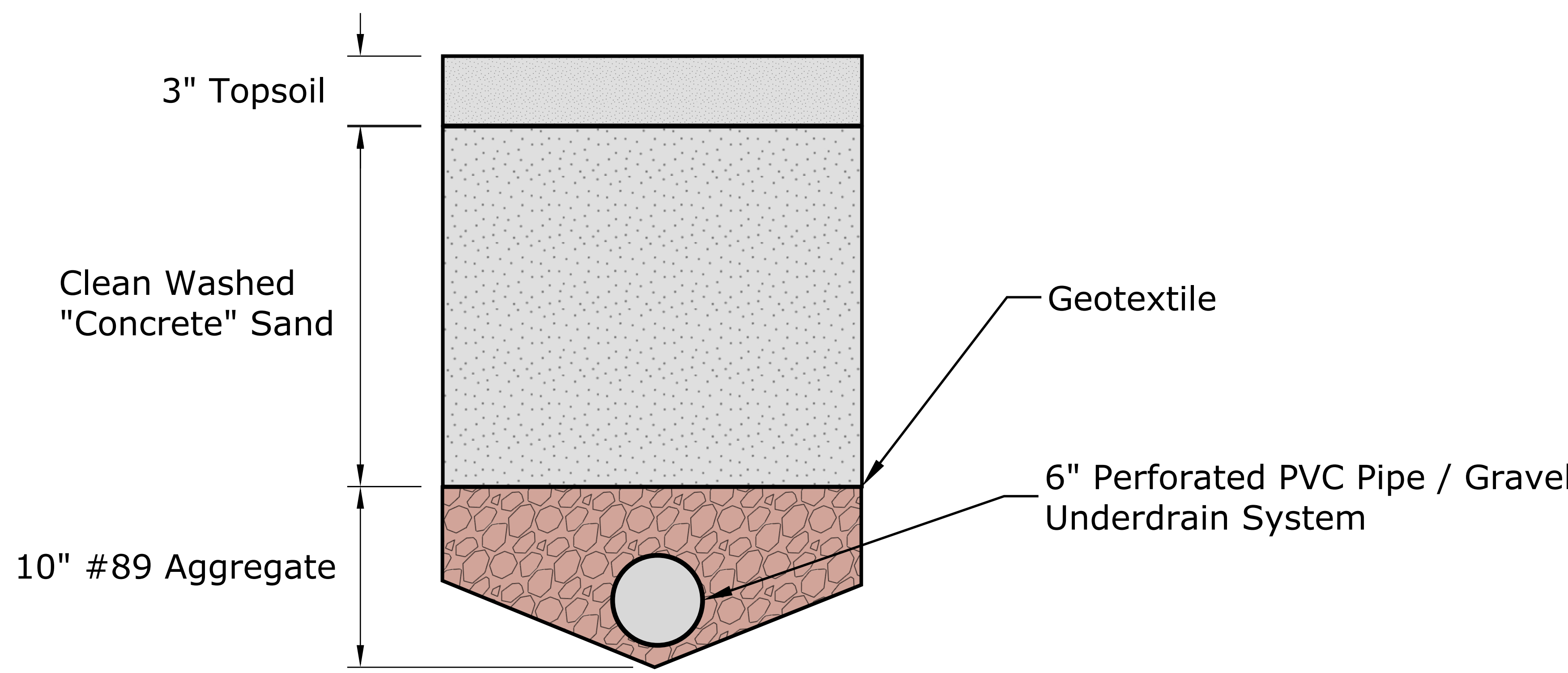
CHAPTER 6.18 SURFACE SAND FILTER



NOTES TO DESIGNERS:

1. SAND DEPTH SHOULD BE MINIMUM OF 18".

PROFILE



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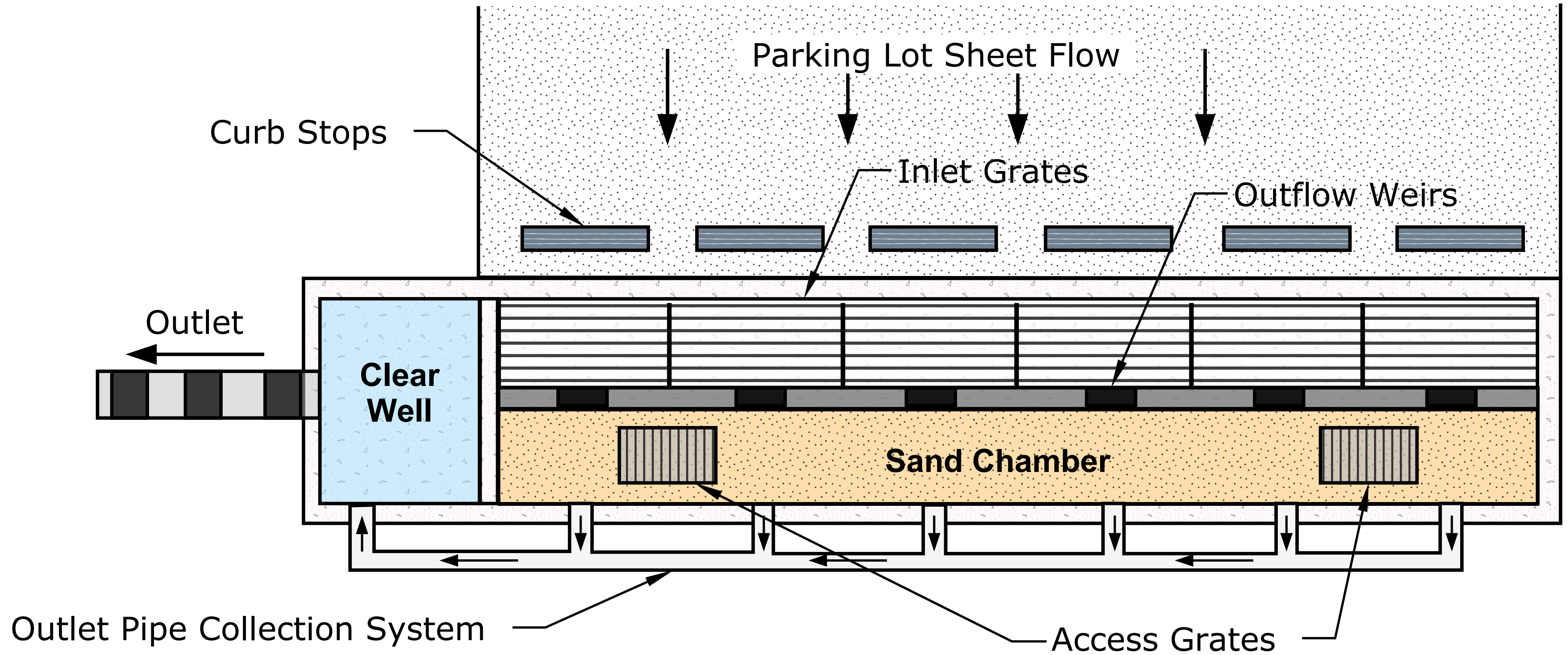
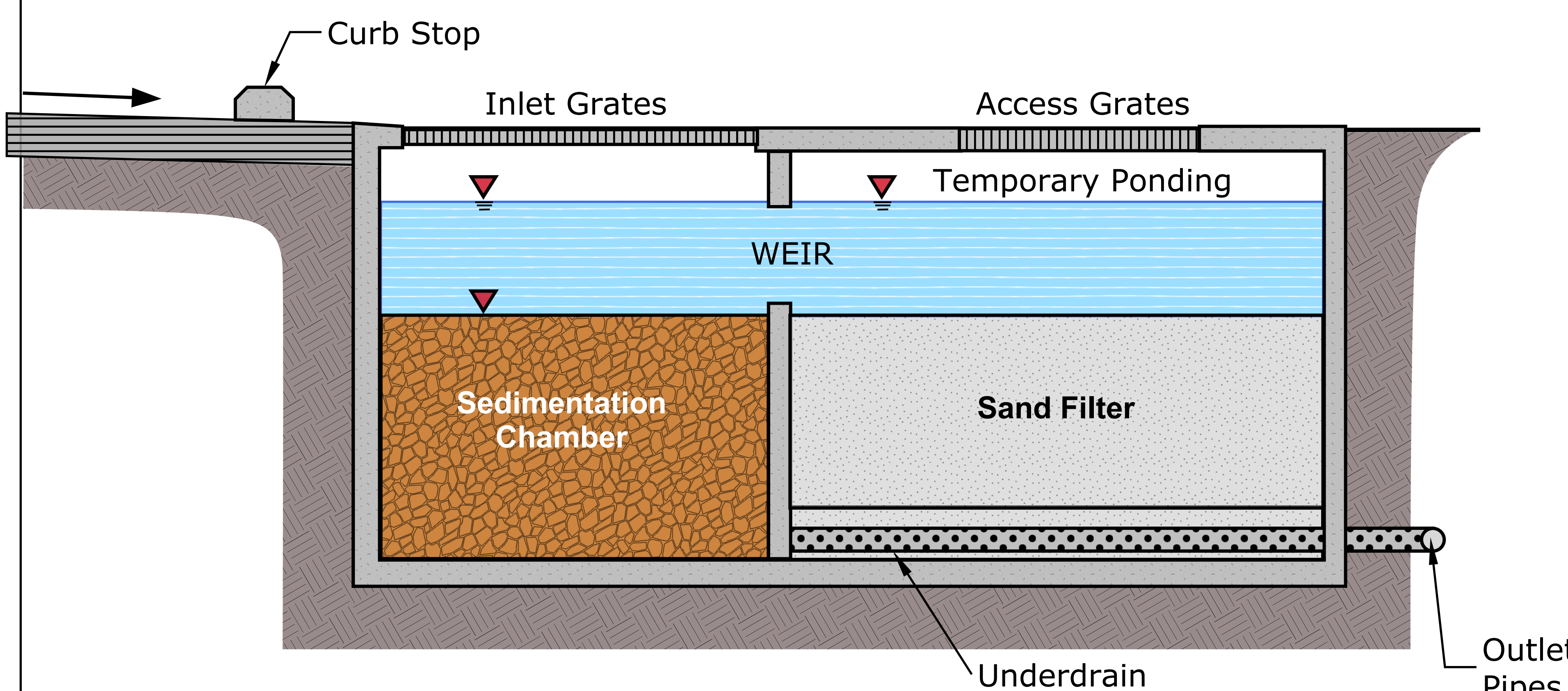
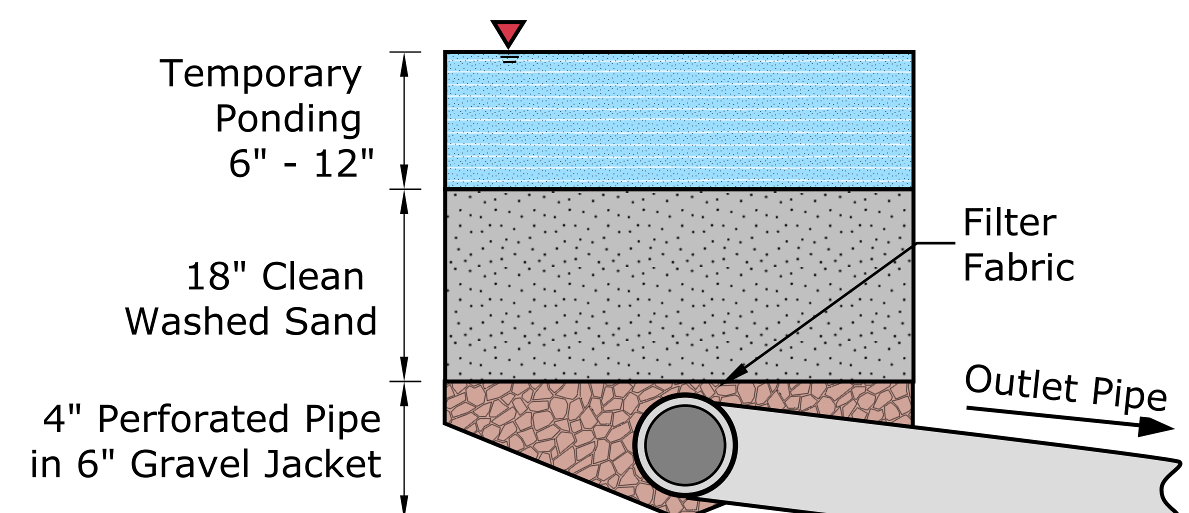
CHAPTER 6.18 SAND FILTER - PERIMETER SAND FILTER



PLAN VIEW





Typical Section

PROFILE