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BMP

Manual of Best Management Practices For Stormwater Quality

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Clean Water. Healthy Life.
Regional Water Quality Education Program

MARC
Mid-America Regional Council

MID-AMERICA REGIONAL COUNCIL

AND

AMERICAN PUBLIC WORKS ASSOCIATION

Manual of Best Management Practices For Stormwater Quality

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EXECUTIVE SUMMARY

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The Kansas City Mid-America Regional Council (MARC) and the Kansas City Metro Chapter of the American Public Works Association (APWA) have developed this manual as a guide for applying stormwater Best Management Practices (BMP) to land development within the Kansas City Metropolitan Area and the MARC planning region. The manual addresses the need to control the volume and quality of stormwater discharges from developed sites, both of which are crucial requirements for protecting human life and property, maintaining overall water quality, and for creating more environmentally sensitive site designs. The authors envision use of this manual alone or in conjunction with the guidelines in Division V of American Public Works Association (APWA) Section 5600, *Storm Drainage Systems & Facilities* design criteria. Communities participating in the program can use state-of-the-art stormwater management practices to meet water quality regulations such as the NPDES Phase II requirements, reduce flooding, conserve water, protect wildlife habitat, and create community amenities.

This manual furnishes clear, understandable guidance for planning and implementing BMPs. It describes how to determine potential water quality impacts and how to select BMPs most appropriate for mitigating those impacts. This manual is based on widely-accepted water quality protection, BMP design, and BMP application guidance from sources throughout the U.S. It adapts this information for use in the Kansas City region. The information includes:

- Definitions for BMPs and water quality treatment concepts
- Stormwater management goals and concepts
- A regionally based procedure for selecting and applying BMPs for a development
- A recommended program of minimum BMPs for all municipalities
- Methods of performing hydrologic calculations for design of water quality treatment
- BMP descriptions and design guidance
- Complete design specifications and standard details for several widely applicable BMPs.

A basic goal for all developments is to maintain predevelopment peak flows, runoff volumes, and water quality. In other words, development should maintain the velocity and quantity of runoff and the amount of pollutants leaving the site, unless the effects are fully considered and documented in the design or unless site conditions apply that require more stringent measures.

Stormwater management proceeds from thorough site analysis to planning and site design, and is unique for each site and development project. The first step in water quality management is to maintain or reduce the amount of runoff generated within a watershed by maintaining watershed hydrology and cover. Treatment is then applied to the remaining runoff to remove some of the pollutant load. BMPs are the key to both approaches and may be non-structural (preserved soils; preserved or established open space and native vegetation; stream buffers) or structural (infiltration, filtration, and extended detention practices designed specifically for water quality treatment).

The "Level of Service Method" presented in this manual was developed specifically for the MARC region. This seven step method for selecting and applying BMP's to development sites utilizes numeric calculations to account for changes in pre to post developed conditions, as reflected by the difference in curve numbers of the two conditions. This difference determines the resultant Level of Service (LS) requirement. LS is indicative of development impacts, which must be mitigated by the site design and incorporation of BMP's. Details of this process are provided in Section 4.

Intended as a regional guidance document, this manual is a reference for BMP application and design. Communities may choose to mandate some or all of its provisions, design criteria and specifications. Jurisdictions are encouraged to adopt this manual in its entirety for maximum benefit and consistency. Those that adopt part of this manual may consider adopting the Initial Measures and Minimum Practices (Section 5), along with the hydrologic calculations, design criteria, and specifications for minimum BMPs from Sections 6 through 8 and Appendix A. Jurisdictions that use this document as a BMP design manual only should consider adopting the implementation portion (Sections 6 to 8 and Appendix A).

Section 1

Introduction

1.0 INTRODUCTION

The purpose of this manual is to facilitate the design and application of stormwater Best Management Practices (BMP) in land development projects within the Kansas City Metropolitan Area and the Mid-America Regional Council (MARC) planning region. The BMP Manual enhances APWA 5600 and helps communities comply with Federal and state water quality regulations.

In 1972, the National Pollutant Discharge Elimination System (NPDES) program was established under the Clean Water Act. NPDES Phase I and Phase II require communities to develop, implement, and enforce a program to reduce pollutants in runoff from new development and redevelopment projects. The manual provides developers and designers with flexible tools which control the volume and quality of stormwater discharges —important for maintaining water quality in our streams, rivers and lakes. Use of this manual alone or in conjunction with the guidelines in Division V of APWA Section 5600 stormwater design criteria can provide a unified, up-to-date strategy for managing stormwater quantity and quality. Unified stormwater management can protect life, property, and the environment, while improving the quality of life for the citizens of the Kansas City region.

As the first attempt to describe state-of-the-art water quality protection practices for the MARC region, the original BMP Manual, developed in 2003, was based on current (though occasionally limited) knowledge. Therefore, the BMP manual was, and continues to be, viewed as a “living document” to be updated periodically with advances in water quality protection practices. This version of the manual is the first update to the original document. The most significant changes include a revised BMP list with updated Value Ratings and an expanded native plant section. Indeed, future versions will reflect lessons learned from implementing the methods and practices currently recommended in this manual– particularly those involving water quality monitoring data and performance assessments.

1.1 BACKGROUND

Recent regional flood events, recognition of the impacts of developed and rapidly developing areas on water quantity and quality issues, and the desire to preserve and protect environmental quality while creating community amenities were the driving forces behind the development of this manual. This manual is an important component of a regionally based program dedicated to combining community planning, engineering design, landscape design and environmental management for the promotion of more environmentally sensitive site designs which reflect an integrated, watershed-based approach to stormwater management. Based on the fact that flood control and water quality are both integral aspects of stormwater management, the guiding philosophy of this program is to “Manage Stormwater Quantity and Protect Water Quality.”

Use of stormwater BMPs is one way to address these two intertwined issues. The term “BMP” originated in the agriculture industry as a reference to practices that reduce farmland erosion and improve crop yield. In the broadest sense, a stormwater BMP is any action or practice aimed at reducing flow rates and pollution concentrations in urban runoff. Examples include site planning practices, public education efforts, open space preservation, pollution prevention practices, and engineered natural treatment systems. This manual describes two classes of BMPs: non-structural and structural. Non-structural controls minimize contact of pollutants with rainfall and runoff. Structural controls are facilities constructed for treating stormwater runoff (Texas Chapter, APWA [Texas APWA] 1998).

1.2 GOALS AND OBJECTIVES

Two primary goals of this integrated stormwater approach are to (1) balance future development with environmental health and quality of life, and (2) comply with water quality regulations such as the National Pollutant Discharge Elimination System (NPDES) Phase II requirements. New, proactive policies and practices are provided in this document which will guide the efforts of municipalities, developers and designers in the achievement of environmentally sound development and resource conservation which will reduce flooding, protect stream corridors, conserve water, improve water quality, preserve wildlife habitat and create community amenities.

This type of balanced development requires we first mitigate and reduce the environmental impact of increased stormwater runoff due to development by controlling the large water quantities produced by developing watersheds and minimizing resulting impairment. Peak flows and overall quantity of stormwater can be maintained, or reduced, after development activities are complete. Stream setbacks, environmentally sensitive site selection and design and the incorporation of BMPs address environmental health and quality of life issues. BMP's, in particular, can improve stormwater quality by mitigating extreme pH values and assisting removal of sediment, petroleum-based materials, biochemical oxygen demand (BOD), metals, bacteria, nutrients, toxic organic compounds, and other substances that may be present in harmful concentrations. Communities adopting these goals and objectives can use state-of-the-art stormwater management practices to meet water quality regulations such as the NPDES Phase II requirements.

1.3 BRIEF DESCRIPTION OF MANUAL

This manual furnishes clear, understandable guidance for planning and implementing BMPs. It describes how to determine potential water quality impacts and how to select BMPs most appropriate for mitigating those impacts. It also describes uses, effective placements, and likely effects of BMPs. Developers of entire communities, individual homeowners, and businesses can use these BMPs. Guidance on water quality protection, BMP design, and BMP application from sources throughout the U.S. are included. This information was adapted for use in the Kansas City region and includes:

- Definitions for BMPs and water quality treatment concepts
- Stormwater management goals and concepts
- A regionally based procedure for selecting and applying BMPs for a development
- A recommended program of minimum BMPs for all municipalities
- Methods of performing hydrologic calculations for design of water quality treatment
- General BMP descriptions and design guidance
- Complete design specifications and standard details for several widely applicable BMPs.

The first half of the manual, Sections 2 through 5, provides general information:

- Section 2 lists definitions of BMPs and other stormwater management terms.
- Section 3 discusses stormwater management goals and concepts, and the "treatment train" approach for placing BMPs in series for additional water quality improvements. As well, this section cites additional BMP application and design guidance documents pertinent to the Kansas City region.
- Section 4 identifies developments that should meet stormwater management goals. Section 4 also provides the recommended procedure for quantifying postdevelopment impacts on a site and selecting a stormwater management system to mitigate those impacts.
- Section 5 describes the basic measures for treating water quality that should be considered as part of a minimum program.

The second half of the manual, Sections 6 -10, includes "nuts and bolts" information on BMP selection and design:

- Section 6 describes the method for modeling hydrology for water quality improvement and BMP design.
- Sections 7 and 8 provide general selection and design criteria for non-structural and structural BMPs.
- Section 9 describes how to tie sediment controls, erosion control, and other regulatory programs into the stormwater management system.
- Section 10 provides a detailed list of references used in the preparation of this document.

1.4 FORMAL ADOPTION OF THIS MANUAL

Intended as a regional guidance document, this manual is a reference for BMP application and design. Communities may choose to mandate some or all of its provisions, design criteria and specifications. Jurisdictions are encouraged to adopt this manual in its entirety for maximum benefit and consistency. Those that adopt part of this manual may consider adopting the Initial Measures and Minimum Practices (Section 5), along with the hydrologic calculations, design criteria, and specifications for minimum BMPs from Sections 6 through 8 and Appendix A. Jurisdictions that use this document as a BMP design manual only should consider adopting the implementation portion (Sections 6 to 8 and Appendix A).

Section 2

Definitions

2.0 DEFINITIONS

Best Management Practice (BMP): Stormwater management practice used to prevent or control the discharge of pollutants and minimize runoff to waters of the U.S. BMPs may include structural or non-structural solutions, a schedule of activities, prohibition of practices, maintenance procedures, or other management practices.

Bioretention: Small engineered and landscaped basins intended to provide water quality management by filtering stormwater runoff before release into stormdrain systems.

Curve Number (CN): A runoff coefficient developed in the U.S. Natural Resource Conservation Service (NRCS) family of hydrologic models by combining land use and one of four hydrologic soil types on a parcel of land.

Detention Storage: The volume occupied by water below the level of the emergency spillway crest during operation of a stormwater detention facility.

Emergency Spillway: A device or devices for discharging water when inflow exceeds designed outflow from a detention facility. The emergency spillway can prevent damage to the detention facility from sudden release of impounded water.

Extended Dry Detention Basin: Any detention facility, vegetated with native plants, designed to permit no permanent impoundment of water but designed to detain the water quality volume for forty (40) hours.

Extended Detention Wetland: A land area that is permanently wet or periodically flooded by surface or groundwater, and has developed hydric soil properties that support vegetation growth under saturated soil conditions. It may have been engineered with adequate capacity to detain large storm flows.

Extended Wet Detention Basin: Any detention facility designed to include a permanent pool and designed to detain the water quality volume for forty (40) hours.

Filter Strip: A grassed area that accepts sheet flow runoff from adjacent surfaces. It slows runoff velocities and filters out sediment and other pollutants. Filter strips may be used to treat shallow, concentrated, and evenly distributed storm flows.

First Flush: The quantity of initial runoff from a storm or snowmelt event that commonly contains elevated pollutant concentrations. Often the first flush contains most of the pollutants in drainage waters produced by the storm event.

Floodplain: A relatively level surface that is submerged during times of flooding. Located at either side of a watercourse, it is composed of stratified alluvial soils built up by silt and sand carried out of the main channel. Activities within floodplains are often regulated by Federal Emergency Management Agency (FEMA) or other regulatory agency.

Hydrologic Soil Group (HSG): NRCS soil grouping according to minimum infiltration rate, or the capacity of soil (absent vegetation) to permit infiltration. Soils are grouped from HSG A (greatest infiltration and least runoff) to D (least infiltration and greatest runoff).

Impact Stilling Basin: A pool placed below an outlet spillway and designed for reducing discharge energies in order to minimize downstream erosive effects.

Impervious Surface: A surface that prevents infiltration of water.

Infiltration: Percolation of water into the ground.

Infiltration Practices: A system allowing percolation of water into the subsurface of the soil. This may recharge shallow or deep groundwater. Basins or trenches may serve as key components of this system.

Infiltration basins: Earthen structures that capture a certain stormwater runoff volume, hold this volume, and infiltrate it into the ground over a period of days.

Infiltration trenches: Small, excavated trenches filled with coarse granular material; they collect first flush runoff for temporary storage and infiltration.

Level of Service (LS): The level of water quality protection recommended for a development or provided by a postdevelopment stormwater management system. The LS requirement for the development is determined by the change in runoff from the predevelopment condition. The LS provided by the stormwater management system is determined by a combination of detention and water quality treatment.

Level Spreader: A structural practice of redistributing concentrated flows to sheet flow over a wide area to minimize erosive velocities, and to increase infiltration and treatment potential.

Media Filtration Practices: Suitable only for runoff from highly impervious stabilized areas these filters consist of a pretreatment area or chamber in conjunction with a self-contained bed of sand used to treat wastewater or diverted stormwater runoff; the water subsequently is collected in underground pipes for additional treatment or discharge.

Surface Sand Filter: Surface sand filters (sometimes referred to as Austin sand filters) use an off-line sediment chamber to collect the first flush of stormwater with larger flows being diverted around the sedimentation chamber.

Perimeter sand filter: Perimeter sand filters use a two-chamber concrete vault and are typically used in a linear application, such as the perimeter of a parking lot.

Underground: Underground sand filters (also called Washington D.C. sand filters) use a three-chamber concrete vault placed at or beneath grade with the existing ground surface.

Pocket: Pocket sand filters (also called Delaware sand filters) are simplified surface sand filters only applicable to small sites. Stormwater must be pretreated by a sediment basin, filter strip, or other means.

Native Soil and Vegetation Preservation: The practice of preserving land areas containing soil profiles and vegetation that have adapted to the climate, hydrology, and ecology of the area to minimize the impacts of development.

Native Vegetation: This term refers to plant types historically located in this geographic area as part of the tall grass prairie, riparian woodland, and oak-hickory forest plant communities. These plant species have not undergone change or improvement by humans, and are still found growing in uncultivated or relatively undisturbed areas within this region. Due to their historic presence, these plant species are extremely well adapted to the climate and natural disturbances (e.g., fire, grazing, and/or flooding) of the region. Furthermore, these plant species have co-evolved with a suite of insects, microbes, and other wildlife. As a result, the grasses, wildflowers, sedges, forbs, shrubs, and trees of these plant communities are drought tolerant, disease and insect resistant, and hardy. Preserved vegetation includes protection of the plant material, as described herein, from destruction and damage, including soil compaction and inundation of sediment. Establishment of native vegetation includes the establishment and maintenance of native plant types and plant associations historically present. Establishment of native plant materials is required if soil treatment is utilized as a BMP.

Natural Channel: Any river, creek, channel, or drainageway that has an alignment, bed and bank materials, profile, bed configuration, and channel shape predominately formed by the action of moving water, sediment migration, and biological activity. The natural channel's form results from regional geology, geography, ecology, and climate.

National Pollutant Discharge Elimination System (NPDES): Defined in Section 402 of the Clean Water Act, this provides for the permit system that is key for enforcing the effluent limitations and water quality standards of the Act. The Phase II Final Rule—published in the Federal Register on December 8, 1999—requires NPDES permit coverage for stormwater discharges from certain regulated, small, municipal, separate storm sewer systems (MS4s) and from land areas greater than 1 acre disturbed by construction.

Pervious Pavement: A type of pavement that allows water to infiltrate the surface layer and enter into a high-void, aggregate, sub-base layer. The captured water is stored in the sub-base layer until it either infiltrates the underlying soil strata or is routed through an underdrain system to a conventional stormwater conveyance system.

Predevelopment: The time period prior to a proposed or actual development activity at a site. Predevelopment may refer an undeveloped site or a developed site that will be redeveloped or expanded.

Principal Spillway: A device such as an inlet, pipe, or weir used to discharge water during operation of the facility under conditions of the design storm.

Proprietary Systems:

> Baffle boxes: Underground retention systems designed to remove settleable solids. There are several water quality inlet designs but most contain one to three chambers. The first chamber provides removal of coarse particles; the second chamber provides separation of oil, grease, and gasoline; and the third chamber provides safety relief if blockage occurs. Frequent maintenance and disposal of trapped residuals and hydrocarbons are necessary for these devices to continuously and effectively remove pollutants.
>
> Catch basin inserts: Catch basin inserts consist of a frame that fits below the inlet grate of a catch basin and can be fitted with various trays that target specific pollutants. Typically the frame and trays are made of stainless steel, cast iron, or aluminum to resist corrosion. The device is typically designed to accept the design flow rate of the inlet grate with bypasses as the trays become clogged with debris.
>
> Hydrodynamic devices: Hydrodynamic devices are engineered systems with an internal component that creates a swirling motion as runoff flows through a cylindrical chamber. The concept behind these designs is that sediments settle out as runoff moves in this swirling path. Typically these devices are prefabricated and come in a range of sizes targeted at specific flow rates. Maintenance requirements include the periodic removal of oil, greases, and sediments, typically by using a vacuum truck.
>
> Media filtration devices: A system that removes pollutants from stormwater by directing the runoff flow through a bed of media contained within a standardized proprietary unit.

Rain Garden: A small depression planted with native wetland and prairie vegetation, rather than a turfgrass lawn, where runoff collects and infiltrates.

Riparian Corridor: Strips of herbaceous and woody vegetation located parallel to perennial and intermittent streams and adjacent to open bodies of water. Riparian Buffers capture sediment and other pollutants in surface runoff water before these enter the adjoining surface waterbody.

Stormwater Detention Facility: Any structure, device, or combination thereof with a controlled discharge rate less than its inflow rate.

Stream Buffer: An area defined by regulatory agencies or municipalities for the protection of riparian corridors and floodplains.

Swale: A depressed area used for stormwater conveyance and/or short term storage.

> Bioswale: An open vegetated channel with an engineered soil matrix and underdrain system designed to filter runoff.
>
> Native Vegetation Swale: Native grasses and forbes planted in a swale to reduce velocity of runoff and promote infiltration
>
> Turf Grass Swale: A swale designed to convey stormwater planted with turf grass. Turf grass swales are meant to be used as a substitute for closed drainage systems.
>
> Wetland Swale: An open vegetated channel without underdrains or soil matrix designed to filter runoff and remain wet between rain events.

Treatment Train: The series of BMPs (or other treatments) used to achieve biological and physical treatment efficiencies necessary for removing pollutants from stormwater (or other wastewater flows).

Tree Preservation: Maintenance of existing trees and shrubs.

Total Suspended Solids (TSS): Matter suspended in stormwater excluding litter, debris, and other gross solids exceeding 1 millimeter in diameter.

Uplands: Lands elevated above the floodplain that are seldom or never inundated.

Value Rating (VR): The assumed water quality improvement value of a cover type or BMP, based on its ability to improve water quality and mitigate runoff volume.

Water Quality: The chemical, physical, and biological characteristics of water. This term also can refer to regulatory concerns about water's suitability for swimming, fishing, drinking, agriculture, industrial activity, and healthy aquatic ecosystems.

Water Quality Storm: The storm event that produces less than or equal to 90 percent stormwater runoff volume of all 24-hour storms on an annual basis. In the Kansas City metropolitan area this is the 1.37" storm.

Water Quality Volume (WQv): The storage needed to capture and treat 90 percent of the average annual stormwater runoff volume. It is calculated by multiplying the Water Quality Storm times the volumetric runoff coefficient and site area.

Watershed: All the land area that drains to a given point (also described as a basin, catchment, and drainage area).

Wetland Treatment System: A stormwater or wastewater treatment system consisting of shallow ponds and channels vegetated with aquatic or emergent plants. This system relies on natural microbial, biological, physical, and chemical processes to treat stormwater or wastewater.

Section 3

Principles of Stormwater Management

3.0 PRINCIPLES OF STORMWATER MANAGEMENT

This BMP manual suggests regional stormwater management goals and, in conjunction with APWA Section 5600, provides a package of technical tools for meeting these goals and NPDES Phase II requirements. The stormwater management goals address both water quantity and water quality. The tools provided are based on several basic water quality concepts. In order to effectively utilize the tools provided, stormwater management design must evolve from thorough site analysis to conceptual planning to a site design, which is unique for each site and development project. Proposed stormwater management system design is sensitive to site characteristics including slopes, soil types, cover types, and infiltration capacity. These characteristics should be considered in the site layout to improve both site drainage and water quality. Additional water quality BMPs may be applied to further reduce pollutants in runoff where water quality goals cannot be achieved through site design alone.

Paragraph 3.1 recommends stormwater management goals for the MARC region. Municipalities should start with these goals as a basis for their stormwater management programs, whether or not they formally adopt APWA Section 5600 and this manual. The goals cover both quantity and quality management and provide options for various watershed conditions and levels of stringency. Paragraphs 3.2 and 3.3 discuss water quality concepts upon which this manual is based and explain how these concepts apply to the water quality BMPs developed to meet water quality goals. This section is not comprehensive – more detailed water quality information may be obtained from the following resources:

- Chapter 1 of the *2000 Maryland Stormwater Design Manual, Volume I* from the Maryland Department of Environment includes a good discussion of basic stormwater management concepts.
- *The Stormwater Manager's Resource Center* (www.stormwatercenter.net) is directed to practitioners, local government officials, and others who need technical assistance on stormwater management issues.

Paragraph 3.4 provides references and a brief description for several other BMP manuals.

3.1 STORMWATER MANAGEMENT GOALS

The basic goal of stormwater management is to align water quantity and water quality management techniques in such a way as to prevent further deterioration of our watersheds. For this reason, water quality criteria has been developed to allow more stringent goals. The three basic techniques for addressing these goals include maintaining existing conditions, decreasing peak flows and reducing pollutants. In addition, it is expected that special management goals may apply on a case-by-case basis.

3.1.1 Maintain Existing Conditions

A basic goal for each development is to maintain or improve predevelopment peak flows, runoff volumes and water quality. In other words, development should not increase the velocity or quantity of runoff, or the amount of pollutants leaving the site. Some exceptions are expected, however. For example, limited increases in either volume or discharge velocity may be acceptable if the effects are fully considered in the design, based on a watershed study or other site-specific analysis. Conversely, it may be necessary to exceed the basic goal and reduce storm water impacts—including peak flows and surface water pollutants—in watersheds currently experiencing serious flooding and water quality problems. The following sections discuss circumstances under which deviations from the basic goal would be apt.

3.1.2 Decreased Peak Flow

One goal that has been established is for each development to maintain predevelopment peak flows. In addition, decreased predevelopment peak flow goals apply to watersheds with specified flood control requirements. In this case the goal is defined as a net reduction in the post-development peak discharge velocity and quantity from predevelopment conditions. Local regulations or officials can determine additional flood control requirements using the results of a watershed study, master plan, or Preliminary Engineering Study.

3.1.3 Improved Water Quality

Improved Water Quality is defined as a net reduction in pollutant discharges from a site. This goal is to produce a qualitative improvement in water quality as a result of development (beyond the "do no harm" approach of maintaining existing conditions). It applies where local stormwater design standards are superseded by a state or federal water quality requirements such as a Total Maximum Daily Load (TMDL) or similar state discharge limit for pollutant or water quality indicator. This goal also may be applied where local authorities require water quality improvement. The governing municipality may set more than one tier of improved water quality using the Level of Service Method described in Paragraph 4.3.

3.1.4 Special Management Goals

Special Management Goals are developed on a case-by-case basis, considering the unique characteristics of a watershed or stormwater project. Municipal regulations or the city engineer establishes the water quality or flood control requirements using results of a watershed study, master plan, or Preliminary Engineering Study. Special management goals may apply where an engineering study indicates a unique flooding risk, where local stormwater design standards are superseded by a state or federal water quality requirement (such as a TMDL or similar state discharge limit for pollutant[s] or water quality indicator[s]), or where local regulations require additional water quality improvement.

3.2 WATER QUALITY CONCEPTS

Studies have shown that atmospheric deposition distributes most stormwater pollutants. A full range of pollutants is present in virtually all runoff—whether from yards, roads, or rooftops—because of this atmospheric redistribution. The pollutants are mobilized and impact surface water quality when rainfall produces runoff that carries the contaminants into surface waters. For this reason, impervious surfaces are the major source of stormwater pollutants in urban areas (Claytor and Schueler 1996). Runoff volumes and peak velocities are determined primarily by the site's cover type and soils, and other factors such as slope, distance, and existing drainage features (USDA 1986). Runoff quantity and water quality are linked, and this linkage forms the basis for this BMP manual.

The first step in water quality management is to maintain or reduce the amount of runoff generated within a watershed. Treatment is then applied to the remaining runoff to remove some of the pollutant load. BMPs are the key to both approaches, as described below.

Preserving a site's infiltration capacity is a relatively inexpensive non-structural measure to reduce runoff rates, volumes, and pollutant loads. Stormwater runoff rates and volumes and water quality are influenced heavily by infiltration capacity (USDA 1986; Claytor and Schueler 1996). Urbanization shortens a watershed's response to precipitation mainly by reducing infiltration and decreasing travel time. An impervious surface decreases travel time by preventing infiltration and speeding runoff. Furthermore, faster runoff velocities reduce the opportunity for pollutants to settle out or be removed by natural processes.

Most urban areas are only partially covered by impervious surfaces, however, and natural infiltration rates to underlying soils are influenced primarily by soil type and by plant cover. Any disturbance of a soil profile and cover type can change infiltration characteristics significantly (USDA 1986). Site designs can preserve existing pervious surfaces (open space and vegetation, especially native species), incorporate pervious landscaping and vegetated cover, and reduce and disconnect impervious cover. Pervious cover, and especially vegetation, allows water infiltration that minimizes runoff, erosion, and potential for downstream pollution. Vegetation helps reduce erosion and filters sediment and other pollutants from stormwater runoff by creating a natural buffer to reduce velocity of surface water. Native vegetation and open space provide aesthetic and habitat benefits. Site development practices also can protect soils from compaction and maintain high-quality native soil characteristics. Section 7 discusses non-structural BMPs in considerable detail.

Communities can improve their water quality significantly by treating the remaining runoff volumes with structural BMPs. Structural BMPs are designed to infiltrate and reduce the amount of runoff, or to filter and detain runoff to reduce discharge velocities and remove pollutants. Infiltration galleries represent an example of the former, while bioretention areas (vegetated depressions designed to collect and treat runoff through an engineered matrix of soils

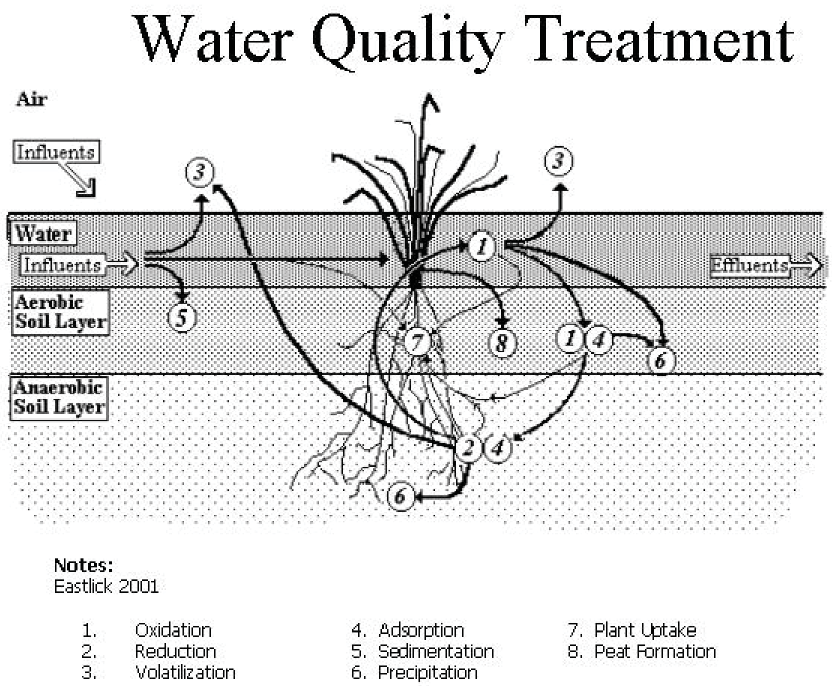


FIGURE 3.1 - Natural Treatment Processes

and plant roots) represent an example of a filtration practice. As shown in Figure 3.1, filtration and detention BMPs remove pollutants by several processes, including physical settling and filtering by plants and soil media, aeration, adsorption onto soils, and biological processes in the root zone.

Not all runoff contains high concentrations of pollutants, however. The initial rainfall, or “first flush”, mobilizes pollutants that have built up on pervious and impervious surfaces. Thus, pollutants are more concentrated in this “first flush,” with concentrations gradually diminishing as rainfall continues. To be efficient and cost-effective, water quality BMPs must be sized and designed to treat this more concentrated runoff rather than the extreme flood events which are managed by conventional stormwater systems. The design storm for water quality BMPs is the water quality volume (WQv). The WQv is defined as the storage needed to capture and treat 90 percent of the average annual stormwater runoff volume. WQv is a function of the Water Quality Storm, which is the storm event that produces less than or equal to 90 percent volume of all 24-hour storms on an annual basis. In the greater Kansas City Metropolitian area, the Water Quality Storm is the 1.37’ rain event.

The following section discusses application of non-structural and structural BMPs.

3.3 TREATMENT TRAIN

A single BMP may not suffice to meet the stormwater management and design objectives for a development. The preferred approach for water quality improvement is a combination or series of stormwater BMPs called a “treatment train.” This set of biological and physical treatments successively removes pollutants from stormwater flows. A treatment train also can reduce the physical volume of runoff, thus reducing stormwater management costs while improving water quality (Texas APWA 1998).

While many practitioners focus on engineered structural BMPs, a treatment train combines site development strategies, management and housekeeping practices, and engineered solutions. What is not imposed on a site or development can be more important than the applied engineered BMPs. Avoidance is the best strategy to deal with most problems – the most cost-effective practice is to limit the generation of runoff by preserving or creating natural areas and vegetation that soak up precipitation, slow runoff, and filter sediment. Engineered solutions then deal with the remaining runoff volume most effectively at the source. Infiltration and filtration BMPs placed at the source also reduce runoff volumes and peak flows from smaller, more frequent storms (see Section 6 for a discussion of water quality and hydrology). Finally, what cannot be absorbed or treated at the source must be routed through larger BMPs for detention and treatment prior to discharge from the site. Pollution prevention is also applied so that contaminants are not released from a site where they can be picked up by runoff and carried into surface water bodies. Selection of treatment train components is based on a combination of local and state stormwater requirements, site characteristics, development needs, runoff sources, financial resources, and BMP characteristics (such as space requirements, design capacities, and construction and maintenance costs).

Before choosing a sequence of treatment practices, a planner must understand the site conditions and hydrologic characteristics of the site's drainage area and the requirements for water quality treatment. Most developments are required to manage stormwater peak flows from the site according to Section 5600 or other local regulations; developments also should provide water quality management, as described in this BMP manual or other local regulation. This BMP manual includes guidelines for determining a development's approximate water quality impact and selecting an appropriate BMP package for the site and development. At a minimum, the predevelopment quality of the site must be maintained. The procedure for ranking the predevelopment condition of the site and for selecting a BMP package that will maintain that condition is referred to as the Level of Service (LS) calculation. This procedure includes a method for determining how much treatment a development should include and is described in Section 4. Methods for determining site hydrology and for calculating the WQv are described in Section 6.

The developer and site design team shall select a combination of practices to meet basic requirements. The "right" treatment train best satisfies stormwater management requirements and project goals and offers the most overall value for the development. Treatment train practices that generally follow the Hierarchy of Stormwater Best Management Practices (see Figure 3.2) usually provide the most benefit, at the least cost, with the with greatest flexibility in addressing stormwater needs within the site design. As reflected in Figure 3.2, preserving native areas or establishing vegetated open space is commonly the first stage of a treatment train. Undisturbed land or land returned to a natural state through native landscaping, enables greater stormwater infiltration which, in turn, minimizes runoff, erosion, and potential for downstream pollution. A site design which includes disconnected impervious surface areas provides opportunities to address pollutants from rooftops, sidewalks, driveways, parking lots, roadways and so on, in the most efficient manner, close to its origin.

Many suburban or urban sites may have land use, design requirements or other constrains which limit the amount of open space available for stormwater management. These sites may require engineered stormwater infiltration practices and treatment, shown in the middle tier of Figure 3.2. These practices and treatment features make up the second stage of the treatment train and control runoff near its source. Examples of infiltration practices include pervious vegetated areas (such as lawns or specially designed filter strips around parking lots and buildings), infiltration trenches and basins, pervious pavement parking lots, and residential rain gardens (Texas APWA 1998). These practices can most efficiently infiltrate site generated runoff and thus substantially reduce runoff that contains pollutants (for example, runoff from the smaller storms such as the Water Quality Storm). Maximizing infiltration results in a reduced peak runoff rate—even from smaller rain events— which decreases demands and stress on downstream control facilities. Peak reduction from reducing impervious surfaces or detaining these smaller events is a function of site and BMP design; it should be calculated and applied by the stormwater designer as part of the design process.

Open space and infiltration practices alone may not sufficiently manage all runoff from a site because of inadequate space, soils and geology, slopes, or other factors. Engineering filtration systems at or near the source of runoff is the next stage of the treatment train. Filtration systems route the most contaminated "first flush" of rainfall through an engineered natural filter. Examples of filtration systems include sand filters, bioretention, wetland swales, and vegetated channels (Center for Watershed Protection 2000b, Claytor and Schueler 1996). These practices also detain smaller rain events, as they are designed to treat the water quality volume.

Designing stormwater detention practices is the last stage of the treatment train. The stormwater engineer or planner should estimate the maximum volume of detention available and required. Detention generally applies to large

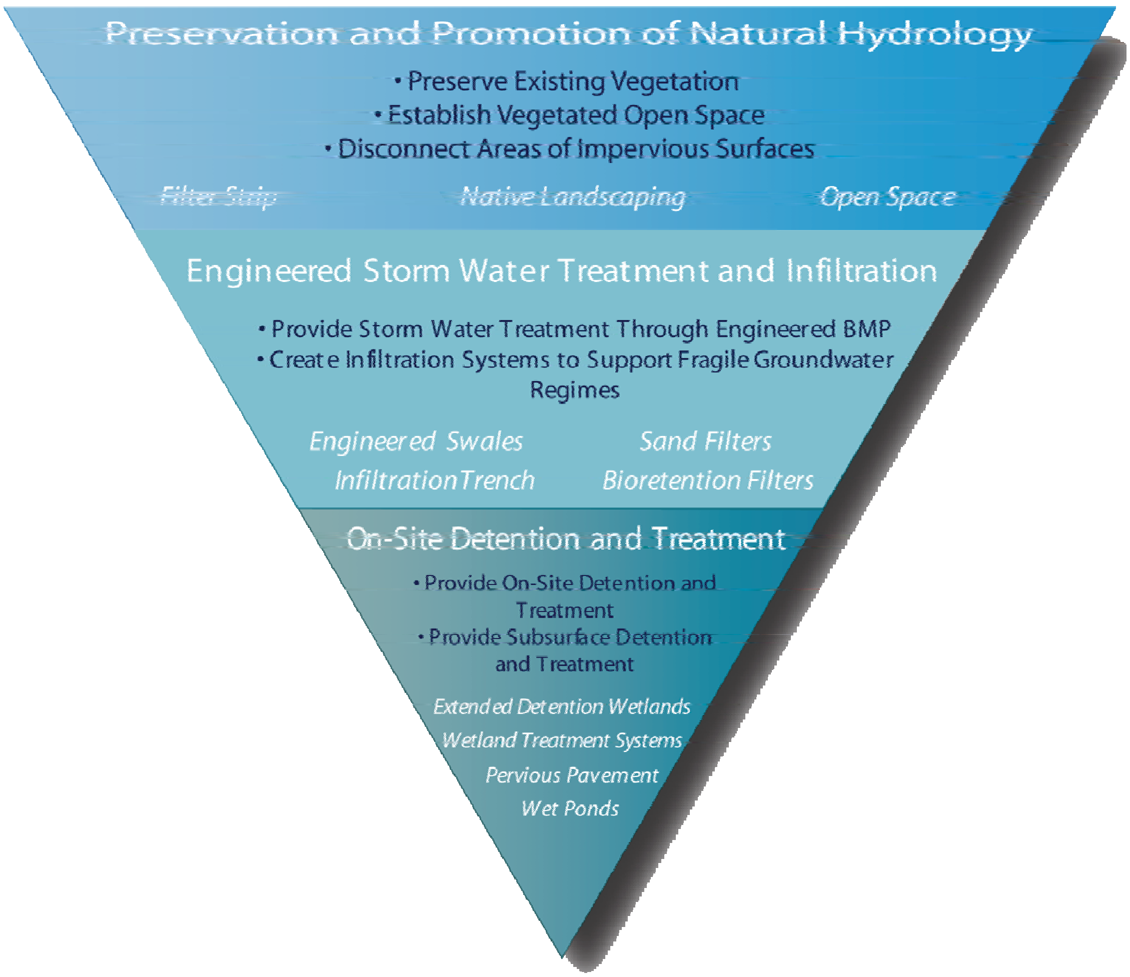


FIGURE 3.2 - Hierarchy of Stormwater Best Management Practices

developments; it provides solutions for sites where space inadequacy precludes stormwater treatment closer to the source. Detention may be the preferred option where predevelopment site conditions are of low quality. Detention basins detain and manage releases from larger rainfall events—usually up to and including the 100-year return interval event – and should include a treatment component sized for the WQv. Many examples and designs are discussed in Section 8.

Finally, proper maintenance and pollution prevention practices can further limit stormwater runoff pollution. Routinely cleaning and periodically refurbishing BMPs is necessary for them to function as designed. Maintenance practices (such as sweeping streets and parking lots) remove pollutants before rainfall can enter surface water from spills and leakage from equipment (Claytor and Schueler 1996). Pollution prevention strategies can contain common sense practices not included in most treatment trains— containment barriers around chemical storage areas to confine potential spills, berms around fueling stations to prevent stormwater run-on, or vehicle and equipment maintenance to prevent leakage (Texas APWA 1998). Appendix B includes information on such practices. Figure 3.3 illustrates an elementary treatment train concept.

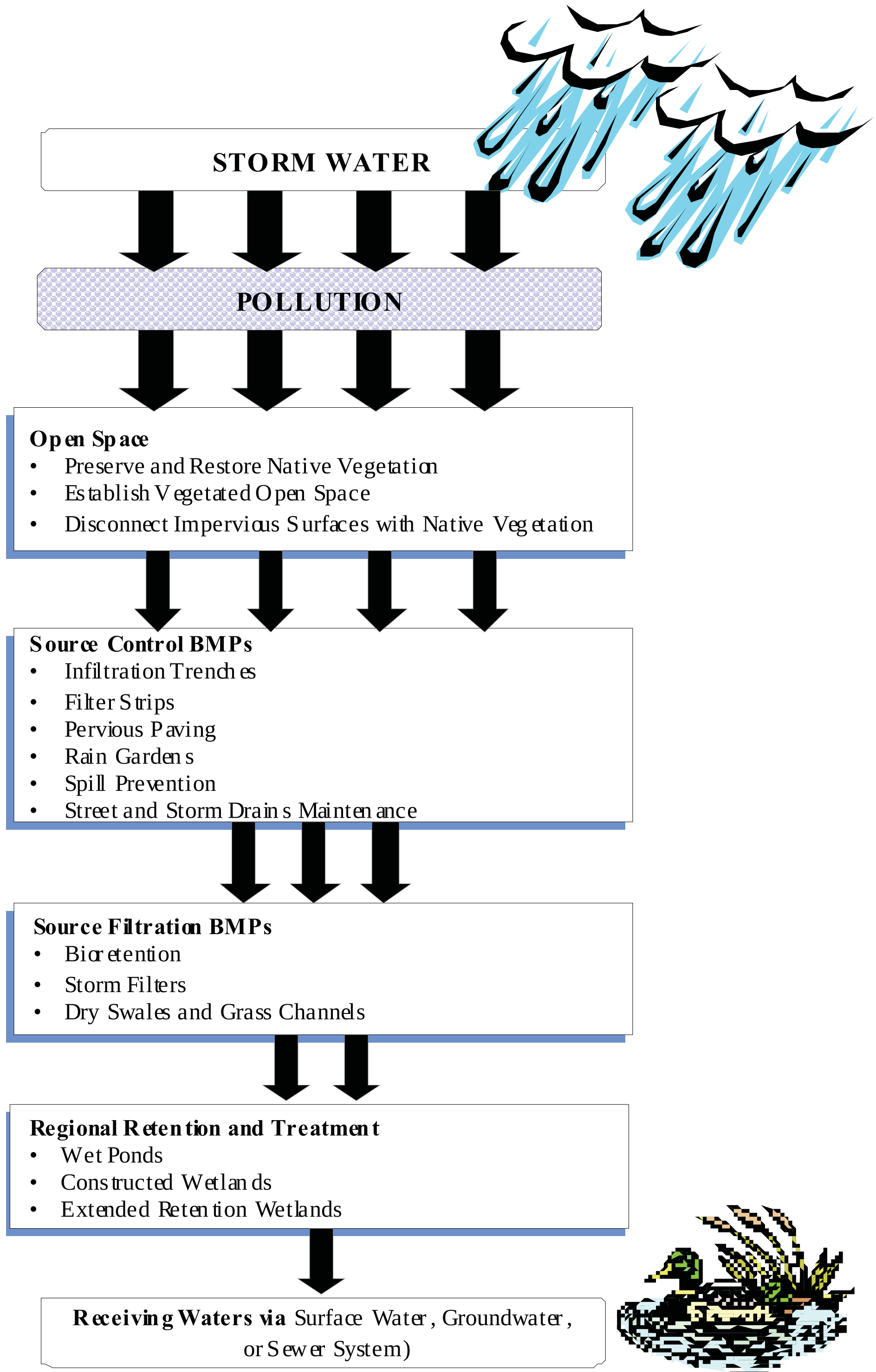


FIGURE 3.3 - Stages of a Treatment Train

The following examples illustrate hypothetical treatment trains for three types of sites:

Residential subdivision: (1) preserve native prairie remnant as common open space; (2) landscape with native vegetation; and (3) use dry swales to convey and treat runoff from landscaped streets and yards.

Commercial development: (1) establish native landscaping in and around buildings and parking areas to break up impervious areas; (2) use bioretention cells in parking lots.

Office park: (1) place filter strips around building downspouts and parking lots, leading to (2) infiltration basins; (3) use dry swales to treat runoff from streets and convey it to (4) a wet pond.

3.4 OTHER REFERENCES AND DESIGN SOURCES

Three useful references for conservation development strategies are:

- Growing Greener Booklet from the National Lands Trust (http://www.natlands.org/planning/growgreen.html)
- Better Site Design: A Handbook for Changing Development Rules in Your Community (http://www.cwp.org/)
- Low-Impact Development Design Strategies – An Integrated Approach (http://lowimpactdesign.org/)

Water quality planners, engineers, and developers may want to consult other manuals and guidance on a case-by-case basis. A number of the better-known methods are described below:

- *2000 Maryland Stormwater Design Manual, Volumes I & II*. Maryland Department of Environment, Water Management Administration. October 2000.

  This State of Maryland publication specifies 14 mandatory performance standards that apply to any construction activity disturbing 5,000 or more square feet of earth. The manual provides selection guidance for pretreatment, non-structural BMPs, and structural BMPs designed to remove 80 percent of the average annual post-development total suspended solids load and 40 percent of the average annual post-development total phosphorous load. The redevelopment policy specifies a 20 percent reduction in impervious surface area below existing conditions. Where impractical due to site constraints, this manual requires the use of BMPs to meet the equivalent in water quality control of a 20% decrease in impervious surface area. Additional BMPs are provided for stormwater "hot spots" or highly polluting land uses. This text also includes a good discussion of basic stormwater management concepts.

- Minnesota Urban Small Sites BMP Manual. Metropolitan Council. July 2001.

  This manual provides voluntary BMP application and design guidance for small sites (less than 5 acres). The manual furnishes general siting and selection criteria, design guidance, and operation and maintenance recommendations for 40 BMPs—along with relative rankings of each based on treatment suitability, physical feasibility, and community acceptance.

- *Stormwater Management Manual, Revision #2*. The City of Portland, Oregon, Environmental Services Department. September 2002.

  The City of Portland requires that all development projects with over 500 square feet of impervious development footprint area, and all redevelopment projects redeveloping over 500 square feet of impervious surface, treat runoff from the additional impervious areas. Portland requires treatment and removal of 70 percent of total suspended solids (TSS) from runoff generated by a design storm up to and including 0.83 inches of rainfall over a 24-hour period. The manual provides a list of acceptable BMPs and simplified sizing and design guidance for each based on the impervious area treated. It also includes a performance-based BMP selection method for designing and customizing BMPs.

- *Texas Nonpoint Source Book*. Texas APWA. 1998. On-Line Address: www.txnpsbook.org.

  This web site provides general guidance for various aspects of stormwater management, including water quality concepts, stormwater programs and utilities, and links to other resources. The site also furnishes general planning criteria, design guidance, and operation and maintenance recommendations for a number of BMPs—and relative rankings of each based on treatment suitability, physical feasibility, and community acceptance.

- *Urban Best Management Practices for Nonpoint Source Pollution*. Wyoming Department of Environmental Quality, Water Quality Division. February 1999.

  This text is a general reference for water quality principles, and for selecting and applying BMPs geared toward semi-arid climates.

- *Urban Storm Drainage Criteria Manual Vol. 3 – Best Management Practices*. Urban Drainage and Flood Control District, Denver, Colorado. September 1999.

  Denver's Urban Storm Drainage Criteria Manual provides water quality management guidance for local jurisdictions, developers, contractors, and commercial and industrial operations. This manual includes discussions of water quality principles and hydrology; in-depth selection and design criteria for a number of BMPs; standard engineering details; operations and maintenance guidelines; and BMP design worksheets. The manual is geared toward semi-arid climates.

Section 4

BMP Selection Criteria

4.0 BMP SELECTION CRITERIA

A number of jurisdictions throughout the U.S. have adopted their own methods for implementing water quality principles into workable development ordinances and design criteria. The "Level of Service Method," presented in the following sections, is a BMP selection method designed for the greater Kansas City region, which has been based on nationally recognized research and practices.

The Level of Service (LS) Method for BMP selection has been developed specifically for the Eastern Kansas-Western Missouri region; it is based on widely accepted research and applied hydrology from the NRCS, as well as water quality studies compiled from a number of sources (USDA 1986; Claytor and Schueler 1996; CWP 2000a). Municipalities that adopt the LS Method as local design criteria for water quality protection will use the procedure to assess predevelopment and proposed postdevelopment site conditions, and to create a BMP package which achieves stormwater design goals for the site. Other municipalities and developers are encouraged to follow this method when making stormwater management decisions.

Paragraph 4.1 outlines the procedure to determine what stormwater quality design requirements apply to a specific development or stormwater improvement project. Paragraph 4.2 discusses how to use the LS Method to design a water quality protection package which meets the requirements. Paragraph 4.3 discusses options for more stringent water quality protection requirements. Additional guidance for "stormwater hot spots" is provided in Paragraph 4.4. Sections 6 through 8 provide BMP hydrology and design guidelines. LS method worksheets and examples are provided in at the end of Section 4.

4.1 DEVELOPMENT CONDITIONS

Stormwater management requirements are based on a combination of the requirements in APWA Section 5600, additional local requirements or exemptions that may apply to general development activities or specific projects, and other watershed-specific conditions (if applicable) such as greater than average flood control needs, water quality impairments (for example, specified TMDLs), or sensitive habitats (for instance, high-quality stream segments). The flow chart in Figure 4.1 will help determine water quality goals and requirements appropriate for development conditions. It describes levels of water quality protection the governing municipality may require and when special watershed conditions apply. If the development or flood improvement project does not rate an exclusion based on the conditions described in the flowchart, the owner or developer would then determine the postdevelopment level of service (LS) to maintain water quality according to the selection procedure provided in Section 4.2.

The flow chart in Figure 4.2 outlines the basic process and the process where special requirements apply.

The LS method is intended to maintain existing water quality conditions for developments that increase impervious cover. More stringent requirements may apply where the municipality actively seeks to improve water quality and reduce flooding as development occurs. Communities may seek to decrease peak runoff velocity and/or volume or improve water quality (or both) in specific watersheds or locations, such as where flooding threatens existing structures or where TMDLs necessitate pollutant reductions.

4.2 THE LEVEL OF SERVICE METHOD

The LS refers to the level of water quality protection recommended for a development or provided by a postdevelopment stormwater management system. The LS requirement for the development is determined by the change in runoff as measured by the change in curve number from the predevelopment condition to the postdevelopment condition. The LS provided by the stormwater management system is determined by applying the VR provided by each BMP to the area of the site from which the BMP treats runoff. If the development or project does not meet the definition of development or is otherwise excluded, BMPs are still recommended.

The intent of setting LS is to create a stormwater management system equivalent or superior to that which existed in the site's predevelopment condition through site design and BMPs. Predevelopment condition depends on whether the site or parts of the site are in a developed or developing area and whether the development is new or an incremental improvement to a previously developed site. The selection procedure adjusts for these factors.

The LS Method is outlined below and described in the following paragraphs. Supporting information for selecting site design strategies and BMPs are included as Tables 4.1 through 4.5. Worksheets and examples are included at the end of Section 4.

To determine the LS for a development, the site must be classified as either undeveloped or redeveloped because different procedures are used for each classification. A project is classified as redevelopment when the existing total impervious surface is 20 percent or more of the total land area of the site, unless determined otherwise by the local jurisdiction. All other sites must follow the procedure for previously undeveloped sites.

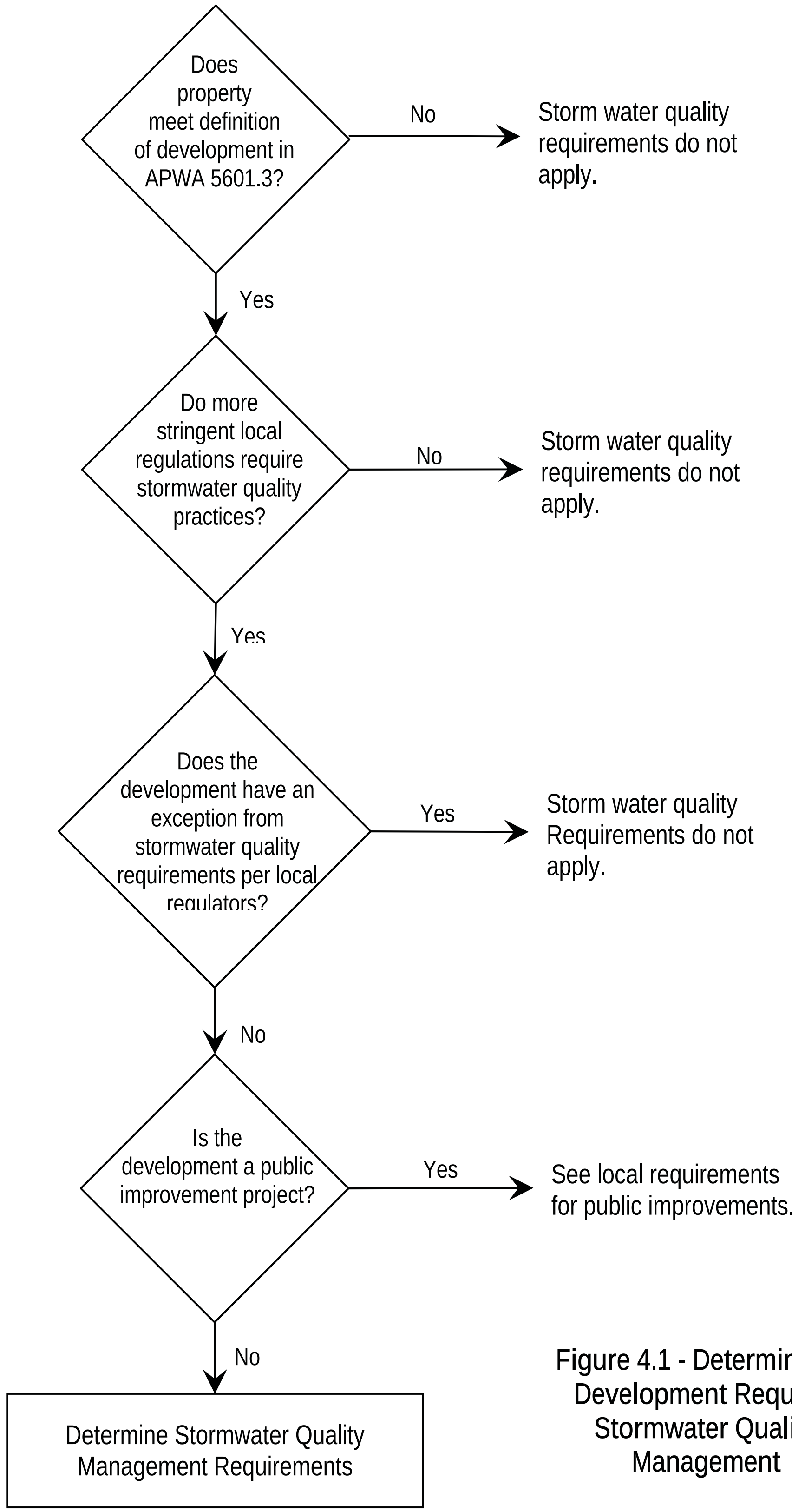
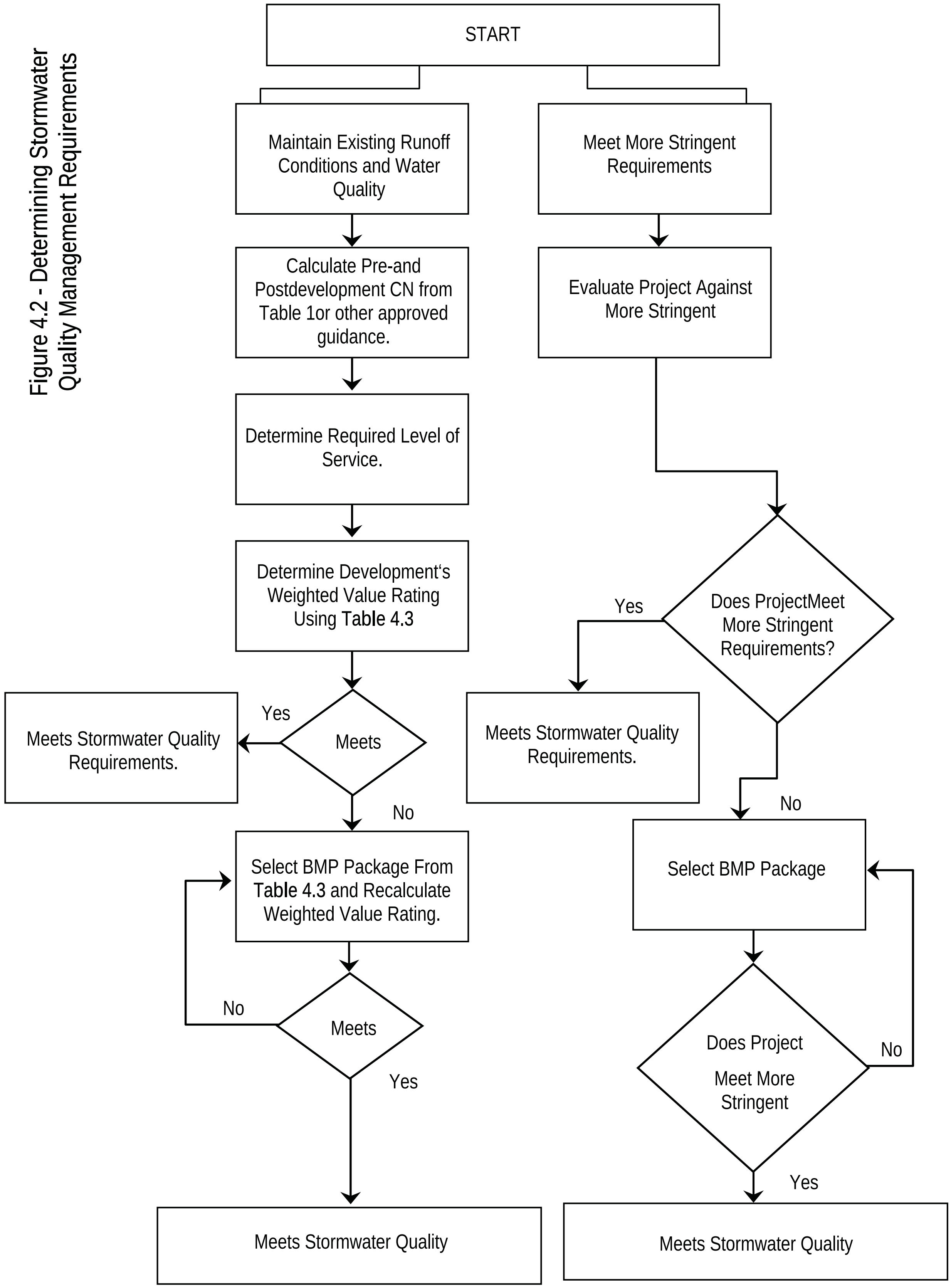


Figure 4.1 - Determining If Development Requires Stormwater Quality Management

Figure 4.2 - Determining Stormwater Quality Management Requirements



The following steps apply to previously undeveloped sites:

Step 1 - Calculate weighted curve number (CN) for predevelopment conditions using Technical Reference No. 55 (TR-55) from the Natural Resources Conservation Service

Step 2 - Calculate weighted CN for the proposed development.

Step 3 - Determine the water quality measures, or LS, that compensates for the difference in predevelopment and postdevelopment CN.

Step 4 - Calculate the weighted Value Rating (VR) provided by the proposed development, including impervious surfaces, vegetative cover, preserved and created vegetation (analogous to TR-55).

Step 5 - If the proposed development's weighted VR will not meet the LS, create a Mitigation Package by applying BMP(s) that would receive and treat runoff from specific areas of the site. BMPs may be non-structural or structural.

Step 6 - Calculate the Mitigation Package weighted VR based on assigned VR for each BMP and the area of the site that the BMP would treat. If the proposed Mitigation Package does not meet the LS, apply different BMPs or apply multiple BMPs in a "treatment train" approach.

Step 7 - Size and design BMPs for optimum water quality treatment per manual specifications.

The steps differ for previously developed sites that are being incrementally modified, such as adding onto existing buildings, or adding new building(s) or parking:

Step 1- Determine the amount of site area to be disturbed by redevelopment activities. Calculate the required area for treatment by subtracting the amount of existing impervious area within the disturbed area from the total disturbed area.

Step 2 - Calculate the proposed percent impervious for the post-development condition by dividing the net increase in impervious area within the disturbed area by the required area for treatment. Enter Table 4.3 with the result to determine the required Level of Service.

Step 3 - Determine the Total Value Rating required for the site in the proposed post-development condition by multiplying the LS by the required area for treatment.

Step 4 - Calculate the Total Value Rating (VR) provided by the proposed development, including impervious surfaces, vegetative cover, preserved and created vegetation (analogous to TR-55).

Step 5 - If the proposed development's Total VR will not meet the required VR, create a Mitigation Package by applying BMP(s) that would receive and treat runoff from specific areas of the site. BMPs may be non-structural or structural.

Step 6 - Calculate the Mitigation Package Total VR based on assigned VR for each BMP and the area of the site that the BMP would treat. If the proposed Mitigation Package does not meet the required Total VR, apply different BMPs or apply multiple BMPs in a "treatment train" approach.

Step 7 - Size and design BMPs for optimum water quality treatment per manual specifications.

The following sections describe the procedure in more detail.

4.2.1 Predevelopment and Postdevelopment Conditions

This section describes the procedure to determine the required LS for the site development. The required LS is determined by the change in CN or imperviousness resulting from the proposed development, and may be influenced by site design choices and BMPs that are introduced into the proposed development plan (See Section 4.2.2).

Calculate the predevelopment condition for a previously undeveloped site by determining the development site's CN or weighted CN using Worksheet 1 at the end of Section 4. The CN is a factor used to estimate stormwater infiltration and runoff for various combinations of soils and cover types; it is determined using the NRCS CN method described in Technical Release 55 (TR-55) (USDA 1986). The predevelopment site condition is determined from: (1) the original cover type(s) and site quality; (2) the hydrologic soil group (HSG) or groups of underlying soils on site as documented in the NRCS soil survey for the county where development is occurring. Soils on sites developed since publication of the soil surveys are assigned a HSG rating one higher than listed in the soil survey (for example, assign HSG C for listed HSG B). For sites with more than one cover type or HSG, determine a CN for each combination of cover type and HSG, and an area-weighted CN for the entire site. Common cover types and the CN for each are provided in Table 4.1, or may be obtained from TR-55, APWA 5602.3, or other sources approved by the governing jurisdiction as applicable.

Use the same method to calculate the postdevelopment condition CN, and then determine the net change in CN from predevelopment to proposed postdevelopment condition. Assume that soils which will be disturbed by development are assigned a HSG rating one higher than the predevelopment condition unless they are preserved in accordance with the specifications in Appendix A. A range of LS scores has been assigned to changes in CN as shown below. The LS rating is based on: (1) documented water quality impacts on watersheds with various levels of imperviousness; (2) assumed percent-impervious surface for various developments contained in TR-55 (CWP 2000b, USDA 1986). Determine the LS that the postdevelopment stormwater management system must provide—find the LS that corresponds to the net change in CN on Table 4.2.

An LS of 4 signifies no change in CN for undeveloped sites, and a LS of 3 signifies no change in percent of impervious surface for previously developed sites. The lower the LS below 4 for undeveloped sites or below LS 3 for previously developed sites, the greater the benefit of development—the proposed development will decrease runoff and improve water quality, thus lowering the development's need to provide "water quality service." Examples of this include a predevelopment poor cover type that is stabilized by the postdevelopment cover, and a retrofit of a previously developed urban site to a new land use with a lower percentage of impervious cover. Site plans that maintain or reduce the CN after development and earn an LS of 4 or less, or in the case of a previously developed site that maintains or reduces the percent impervious area, would not meet the definition of development as stated in APWA 5601.3 and would not require additional stormwater BMPs. However, local jurisdictions may have a more stringent definition of development, or may require or encourage BMPs to be considered for all developments, in which cases the lower LS may apply. Examples 1 and 2 at the end of Section 4 illustrate the CN calculation and LS determination for two hypothetical, undeveloped sites.

Important: A reduction of the CN over part of a site reduces the weighted CN for the overall project. Recalculate the postdevelopment CN and change in CN any time the proposed site design changes so the project's LS is adjusted correspondingly.

Incremental improvements to a previously developed site will cumulatively increase runoff and pollutant discharge. In this case, the water quality impact can be determined by analyzing the impact of the new impervious surface on the site within the disturbed area by calculating the percent impervious surface in the proposed post-development condition of the disturbed area. Example 3 at the end of this section illustrates the LS determination for a hypothetical, previously developed site when all treatment alternatives are contained within the disturbed area.

To the maximum extent practicable, the BMPs used to meet the required Level of Service should be located within the disturbed area of the redevelopment site. However, subject to local jurisdiction approval, BMPs may be located elsewhere on the owner's site if they treat previously untreated runoff or form part of a treatment train. Treatment of offsite drainage areas that drain to the site as a method of meeting onsite Level of Service requirements is strongly discouraged and subject to local jurisdiction approval.

TABLE 4.1
Common Cover Types and Curve Numbers

How To Use This Table:

1. This table presents the cover types that a site planner is most likely to encounter, but is not all-encompassing. See TR-55 for additional information.
2. Site planners may substitute curve numbers from APWA 5602.3 or other local regulations, if applicable, to be consistent with hydrology calculations.
3. "Undeveloped" cover types may be used on portions of developed sites where preexisting cover is preserved and protected from disturbance.
4. Postdevelopment HSG is assumed to be one group higher in runoff than predevelopment, unless soil treatment plan is provided to document otherwise. See Appendix A for soil preservation guidance.

UNDEVELOPED					**DEVELOPED**			
Cover Type	**Condition**	**CN by Hydrologic Soil Group (HSG)**			**Cover Type**	**CN by HSG**		
		B	C	D		B	C	D
Fallow, bare soil		86	91	94	Parking lots, roofs, streets with sewer, water, etc.	98	98	98
Fallow, crop residue	Poor	85	90	93	Commercial, business	92	94	95
Fallow, crop residue	Good	83	88	90	Streets: paved, open ditch	89	92	93
Straight row crops	Good	78	85	89	Industrial (or office park)	88	91	93
Contoured crops	Good	75	82	86	Newly graded areas	86	91	94
Contoured and terraced crops	Good	71	78	81	Streets: gravel	85	89	91
Pasture	Poor	79	86	89	Streets: dirt	82	87	89
Pasture	Fair	69	79	84	Residential, 1/8-acre	85	90	92
Pasture	Good	61	74	80	Residential, 1/4-acre	75	83	87
Woods-grass	Poor	67	77	83	Residential, 1/3-acre	72	81	86
Woods-grass	Fair	65	76	82	Residential, 1/2-acre	70	80	85
Woods-grass	Good	55	70	77	Residential, 1-acre	68	79	84
Woods	Poor	66	77	83	Residential, 2-acre	65	77	82
Woods	Fair	60	73	79	Open space (turf), poor	79	86	89
Woods	Good	55	70	77	Open space (turf), fair	69	79	84
Meadow		58	71	78	Open space (turf), good	61	74	80
Brush-weeds-grass	Poor	67	77	83	Native grass	58	71	78
Brush-weeds-grass	Fair	56	70	77	Native grass, shrubs and forbs (formal plantings)	56	70	77
Brush-weeds-grass	Good	48	65	73	Native grass, shrubs and forbs (informal plantings)	48	65	73

Source: U.S. Department of Agriculture, Natural Resource Conservation Service Urban Hydrology for Small Watersheds, Technical Release 55 (TR-55; 1986)

TABLE 4.2
LS for Previously Undeveloped Sites

Change in CN	Impact	LS
17 or greater	High water quality impact	8
7 to 16	Moderate water quality impact	7
4 to 6	Low water quality impact	6
1 to 3	Minimal water quality impact	5

A cumulative water quality impact from an increase of one or more ranges of percent impervious cover must be mitigated. The LS ratings corresponding to these increases in range are as follows:

4.2.2 Postdevelopment BMP Selection

This section describes the procedure to create a stormwater management plan that meets the required LS. Water quality protection strategies include site design choices and BMPs. Site design options include minimizing and disconnecting impervious cover using low-impact design. BMPs include both non-structural approaches (such as preserving existing vegetative buffers or establishing native landscaping) and structural approaches (such as installing a wet detention pond, bioretention cell, or engineered swale). Site design that incorporates nonstructural BMPs will reduce the site's postdevelopment CN and may reduce the corresponding LS.

The first step is to determine the water quality protection value of the initial site plan and stormwater management system. Water quality protection value is based on the VR of cover types or BMPs that provide water quality treatment for all or part of the site. The VR ranks a cover type's or BMP's assumed value based on its water quality treatment efficiency and ability to retain stormwater. Higher VRs are given for increased water quality improvement value. Table 4.4 lists the VR for native vegetation (which includes both preserved existing vegetation or established native landscaping) and for several common classes of structural stormwater BMPs for which design guidance is provided in this manual.

A VR is the sum of several stormwater management factors. The water quality factor rates assumed pollutant removal potential based on the expected median event mean concentrations of total suspended solids (TSS) in discharges from each class of BMP. These rankings were developed from studies in the International BMP Database (www.bmpdatabase.org; *Analysis of Treatment System Performance, International Stormwater Best Management Practices [BMP] Database 1999-2005*, February 2006). Data were available from all BMP classes for TSS, which is one of the most important pollutants to control and is a good proxy for many other pollutants that adsorb to sediment particles. The VR rates three other factors recommended by the U.S. Environmental Protection Agency: (1) volume reduction (i.e. detention and evapotranspiration value); (2) temperature reduction; and (3) oil and floatables reduction, which also addresses some course sediments. Table 4.5 provides the VR rating system and calculations. Appendix C includes water quality references.

TABLE 4.3
Required Level of Service for Previously Developed Sites

Proposed % Impervious within Disturbed Area	LS	Proposed % Impervious within Disturbed Area	LS
1	3.1	51	5.6
2	3.2	52	5.7
3	3.2	53	5.7
4	3.3	54	5.7
5	3.4	55	5.7
6	3.5	56	5.8
7	3.6	57	5.8
8	3.7	58	5.8
9	3.7	59	5.8
10	3.8	60	5.8
11	3.9	61	5.9
12	3.9	62	5.9
13	4.0	63	5.9
14	4.1	64	5.9
15	4.2	65	6.0
16	4.2	66	6.0
17	4.3	67	6.0
18	4.4	68	6.0
19	4.5	69	6.1
20	4.6	70	6.1
21	4.7	71	6.1
22	4.8	72	6.1
23	4.8	73	6.2
24	4.9	74	6.2
25	5.0	75	6.2
26	5.0	76	6.2
27	5.1	77	6.3
28	5.1	78	6.3
29	5.1	79	6.3
30	5.1	80	6.3
31	5.2	81	6.4
32	5.2	82	6.4
33	5.2	83	6.4
34	5.2	84	6.1
35	5.2	85	6.4
36	5.3	86	6.5
37	5.3	87	6.5
38	5.3	88	6.5
39	5.3	89	6.5
40	5.4	90	6.6
41	5.4	91	6.6
42	5.4	92	6.6
43	5.4	93	6.6
44	5.5	94	6.7
45	5.5	95	6.7
46	5.5	96	6.7
47	5.5	97	6.7
48	5.6	98	6.8
49	5.6	99	6.8
50	5.6	100	6.8

TABLE 4.4
Best Management Practice Value Ratings

Cover Type or BMP	Median Expected Effluent EMC TSS (mg/L)[a]	Value Ratings				Overall Value Rating
		Water Quality Value	Volume Reduction	Temperature Reduction	Oils/ Floatables Reduction	
Vegetation	N/A	5.25	2	1	1	9.25
Native Vegetation preserved or established						
Rain Garden	< 10	4	2	1	2	9.0
A small residential depression planted with native vegetation designed to capture and infiltrate runoff						
Infiltration Practices	< 10	4	2	1	2	9.0
Infiltration Basin						
Infiltration Trenches						
Bioretention	< 10	4	1.5	1	2	8.5
Small engineered and landscaped basins designed to filter runoff before release						
Pervious or Porous Pavement	10-20	3	1.5	1	2	7.5
Pervious Concrete						
Porous Asphalt						
Modular Concrete Block						
Extended Detention Wetland	< 10	4	2	0	1	7.0
A land area that is permanently wet with hydric soils sized to detain the WQv for a minimum of 40 hours.						
Wetland Swale	10 - 20	3	1.5	0	2	6.5
An open vegetated channel without under drains or soil matrix designed to remain wet between rain events.						
Bio-swale	10 - 20	3	1.5	0	2	6.5
An open vegetated channel with an engineered soil matrix and under drain system designed to filter runoff						
Media Filtration Practices	< 10	4	0	0	2	6.0
Surface Sand Filter						
Underground Sand Filter						
Pocket Sand Filter						
Perimeter Sand Filter						
Extended Wet Detention	10 - 20	3	2	-1	1	5.0
A basin intended to have a permanent pool and sized to detain the WQv for a minimum of 40 hours						
Vegetated Filter Strip	10 - 20	3	1	0	1	5.0
Buffer strip with native vegetation trating sheet flow						
Native Vegetation Swale	10 - 20	3	1	0	0	4.0
Native grasses and forbes planted in a swale to reduce velocity of runoff and promote infiltration						
Extended Dry Detention Basin	20 - 50	2	1	0	1	4.0
A basin line with native plant species designed to detain the WQv for a minimum of 40 hours with no permanent						
Turf Grass Swale	10 - 20	3	0	0	0	3.0
Typical turf type grasses are used in swale						
Other Systems	50 - 100 [(b)]	1	0	0	2	3.0
Proprietary Media Filtration Devices						
Hydrodynamic Devices						
Baffle Boxes						
Catch Basin Inserts						

Notes:

TSS Total suspended solids

mg/L Milligrams per liter

a Expected median event mean concentrations of TSS is based on analysis of studies in International BMP Database www.bmpdatabase.org

Source: *Analysis of Treatment System Performance, International Stormwater Best Management Practices (BMP) Database 1999-2005*. Feb. 2006

b Jurisdiction may allow higher score if independent 3rd party field data shows lower expected event mean concentrations TSS in the effluent. However if the proprietary BMP relies on sedimentation as the primary pollutant removal mechanism then performance data over the range of particle size distributions must be submitted for the range of expected flow rates.

TABLE 4.5
Value Rating Calculations

A	Water Quality Value Rating System	0	1	2	3	4+
	Median Concentration of TSS in Effluent (milligrams per liter)	> 100 mg/L	50 - 100 mg/L	20 - 50 mg/L	10 - 20 mg/L	<10 mg/L
B	Volume Reduction Rating System	0	1		2	
		Little or no volume reduction	Moderate infiltration or evaporation		Significant infiltration and evaporation	
C	Temperature Reduction Rating System	-1	0		1	
		Runoff temperature increases	Runoff temperature is unchanged		Runoff temperature decreases	
D	Oils/Floatables Reduction Rating System	0	1		2	
		Little or no oils/floatables reduction	Moderate capture or reduction of oils/floatables		Significant capture or reduction of oils/floatables	

Note:
Value Rating Calculation: VR = A + B + C + D

VR is calculated using the following formula:

$$VR = A+B+C+D$$

Where

A = Water quality value

B = Volume reduction

C = Temperature reduction

D = Oil and grease removal

Note that impervious cover (pavement, roof tops), turf grass lawns, and stormwater management practices that are not designed for water quality treatment such as dry detention basins are not assigned a VR. These cover types and stormwater management practices provide little to no treatment value. BMPs that are not listed in this manual or BMPs that may be custom-designed for a site will not have a VR, of course. However, innovation is not discouraged; designers and reviewers may propose "non-standard" practices based on sound designs and independent monitoring data, and evaluate them against the criteria in Tables 4.4 and 4.5 to assign a VR on a case-by-case basis.

Calculate the area-weighted VR for the overall site using Table 4.4 and Worksheet 2 at the end of Section 4. Begin by assessing the initial site development plan. Multiply the VR scores of any proposed structural BMPs by the catchment area that flows into them, or multiplying the VR for native vegetation by the area of preserved or established native vegetation. The BMP square footage should be included in the catchment area that flows into the facility. Then sum the products and divide by the total site area to produce an area-weighted value. This step is analogous to the weighted CN that is calculated following TR-55. The resulting total is the weighted VR for the proposed stormwater management system. The weighted VR of the proposed development must meet or exceed the required LS. For example, if the required LS for the proposed development is 6, the weighted VR of the proposed stormwater management plan must meet or exceed 6.00 (rounding is not allowed).

If the proposed site plan's weighted VR will not meet the LS, create a Mitigation Package by applying BMP(s) that would receive and treat runoff from specific areas of the site. BMPs may be non-structural or structural. Calculate the Mitigation Package weighted VR based on the assigned VR for each BMP and the area of the site that the BMP would treat. If the proposed Mitigation Package does not meet the LS, test different combinations of site design and BMPs until the optimum Mitigation Package is attained.

Just changing the proposed site design (such as increasing the amount of pervious cover, preserving more native vegetation, or increasing the amount of native landscaping) may reduce the weighted CN or percent imperviousness sufficiently to lower the required LS—for example, from a 7 to a 6. LS should be recalculated for any water quality protection packages that change site cover. If a selected site design feature or BMP will decrease the proposed development's CN (for previously undeveloped sites) or percent imperviousness (for previously developed sites), recalculate the weighted CN or percent imperviousness as appropriate and recalculate the LS. Then compare the weighted VR to the revised LS. Examples 1 and 2 at the end of the section illustrate revised CN and LS calculations.

Treatment trains may be included in the Mitigation Package to improve its performance and weighted VR. As discussed in Section 3, a treatment train is two or more BMPs in series that provide cumulative water quality benefits. Although treatment train functions are not thoroughly documented, in general the effects are determined by the BMPs physical, chemical, and biological processes that function within each BMP and as flow progresses from one BMP to the next (Minton 2005). The VR (Tables 4.4 and 4.5) is designed to rank the relative effects of the processes occurring within each BMP on the four most important water quality factors. The treatment train evaluation is designed to rate the relative effects of two or more BMPs in series based on these same processes, as described below.

The interaction of the physical, chemical, and biological processes may benefit some or all of the water quality factors included in the VR and in some cases may reduce performance for a given factor and the overall VR. Just as the first BMP removes pollutants from the flow, an additional BMP placed in series may remove some of the remaining pollutants although the effectiveness diminishes with each BMP. The latest research indicates that there is an overall limit to water quality treatment for most pollutants, however (www.bmpdatabase.org; *Analysis of Treatment System Performance, International Stormwater Best Management Practices [BMP] Database 1999-2005*, February 2006). BMPs that include floatation and sedimentation processes remove oil, floatables and coarse sediments and are very effective in most cases. In most cases the final BMP in a treatment train, particularly detention practices, will have the greatest impact on the temperature reduction factor. For these reasons the effective value of the secondary practice is a function of the effectiveness of the primary practice. However, each BMP may provide detention and increase the cumulative volume reduction.

Table 4.6 provides composite VRs for the most realistic combinations of two BMPs in a treatment train. BMPs in a treatment train treat runoff from the same portion of the site. The total treatment area cannot exceed the total site area, however. When applying a treatment train in a Mitigation Package, *the VR applies to the treatment train combination*, not the individual BMPs. Example 2 at the end of Section 4 demonstrates how to apply treatment trains to weighted VR calculations. Table 4.6 values were calculated using the following formula:

$$VR1+VR2 = (A1+A2) + (B1+B2) + C2 + (D1+D2)$$

Where

VR1 = VR for the first BMP in series

VR2 = VR for the second BMP in series

A1 through D1 = VR factors from Table 4.4 for the first BMP in series

B2 through D2 = VR factors from Table 4.4 for the second BMP in series

The sum of the water quality factors (A1+A2) may not exceed 4.00, or 4.25 if native vegetation is used, and the sum of the oil and floatables factor (D1+D2) may not exceed 2.00. Example 2 at the end of Section 4 includes treatment trains.

Three or more BMPs may be applied in series, although the marginal increase in VR and performance may not justify the cost. If three BMPs are applied in a treatment train, use the formula above to calculate the VR. Use the composite VR from Table 4.6 for the first two BMPs as VR1 and the VR for the third BMP as VR2. Additional BMPs may be calculated in a similar fashion, provided that only the ultimate composite VR is applied to the site area treated by the treatment train.

Worksheets for selecting water quality protection packages are provided at the end of Section 4, along with examples.

Finally, BMPs selected to achieve the appropriate LS must be selected carefully by considering their suitability to the site's unique conditions. Consideration should be given to targeting the pollutants expected to come from the site. A BMP's ability to remove given pollutants is referenced in section 8. Before making a final selection, the designer should also consult the design guidance in Sections 7 and 8 and the "hot spot" guidance in Appendix C to determine whether a BMP or BMPs are feasible for the development site and to evaluate appropriate land uses, treatment suitability, physical feasibility, relative cost, and community and environmental benefits. If a BMP is not feasible or suitable for the site, evaluate additional BMPs and their corresponding design guidance to select a Mitigation Package that is feasible and meets the LS. Similarly, if the site design changes, revise the LS determination and Mitigation Package selection to meet the requirements and constraints of the new site design.

4.3 ADJUSTMENTS FOR INCREASED WATER QUALITY

Communities may require developments to meet more stringent water quality standards than the basic LS Method, which is designed to maintain predevelopment water quality. Three basic methods are described below.

One way to adjust the LS Method for improved water quality is to require developments that rate an LS of 4 or less to apply BMPs to meet the LS. In some instances meeting an LS less than 4 may require BMPs; for example, redeveloping a shopping mall with residential housing would likely reduce the sites weighted CN, but turf grass lawns do not provide treatment and would not receive a VR. In this case BMPs such as rain gardens, swales, or bioretention might be required to meet the LS.

A second way to accomplish this is to stipulate that the LS provided by the BMP package exceed the base LS by a given amount. Testing this system on both hypothetical and actual site development plans indicates that an LS increase of 0.50 or 1.00 is achievable and would increase water quality treatment significantly over the basic model. A community can adopt these thresholds (LS + 0.50 and LS + 1.00) to create a two- or three-tiered hierarchy of water quality standards based on development size or type, or other criteria appropriate to the community's water quality goals. This system could also be used to calculate and assign "water quality credits" that apply to other areas or phases of the project or to other developments.

A third way to increase water quality treatment is to require BMPs for all impervious surfaces. While such a requirement would ensure considerable water quality treatment, the LS Method would no longer function and some site design flexibility would be lost. Communities that wish to require BMPs for all impervious surfaces could allow site designers to select BMPs based on the hydrology and design criteria in Sections 6 through 8 of this manual.

Meeting a more stringent standard requiring the LS to rise may need extensive use of "treatment trains" to increase the VR of selected BMPs. Section 3 describes treatment train concepts. Section 4.2.2 provides guidance for applying treatment trains.

TABLE 4.6
Composite Value Ratings for Two BMPS in Series

Treatment Train Formula: VR1+VR2 = (A1+A2)* + (B1+B2) + C2 + (D1+D2)**

* **Sum of Water Quality (A1+A2) may not exceed 4.00, or 5.25 if native vegetation is used.**

** **Sum of Oil/Floatables (D1+D2) may not exceed 2.00.**

VR 1 (First BMP in Series)			VR 2 (Second BMP in Series)														
			Cover Type or BMP	Vegetation	Rain Garden	Infiltration Practices	Bioretention	Pervious or Porous Pavement	Extended Detention Wetland	Media Filtration Practices	Wetland Swale	Bio-swale	Extended Wet Detention	Vegetated Filter Strip	Native Vegetation Swale	Turf Grass Swale	Other Systems	Extended Dry Detention Basin
			Overall Value Rating	9.25	9.0	9.0	8.5	7.5	7.0	6.0	6.5	6.5	5.0	5.0	4.0	3.0	3.0	4.0
Cover Type or BMP		**Overall Value Rating**	**VR1+ VR2[a,b,c]**															
Vegetation	N/A	9.25			12.25	12.25	11.75	11.75	11.25	9.25	10.75	10.75	10.25	10.25	9.25	**8.25**	9.25	10.25
Rain Garden	< 10	9.0																
Infiltration Practices	< 10	9.0																
Bioretention	< 10	8.5			10.50	10.50	10.00	10.00	9.50	**7.50**	9.00	9.00	**8.50**	**8.50**	**8.50**	**7.50**		8.50
Pervious or Porous Pavement	10-20	7.5				10.50	10.00		9.50	7.50	9.00	9.00	8.50	8.50	8.50	7.50		8.50
Extended Detention Wetland	< 10	7.0							10.00		9.50	9.50	9.00	9.00	8.00	7.00		9.00
Media Filtration Practices	< 10	6.0				9.00	8.50		8.00	6.00	7.50	7.50	7.00	7.00	7.00	6.00		7.00
Wetland Swale	10 - 20	6.5							9.50				8.50	8.50				
Bio-swale	10 - 20	6.5			10.50	10.50	10.00		9.50	7.50	9.00		8.50	8.50	8.50	7.50	7.50	8.50
Extended Wet Detention	10 - 20	5.0							10.00		9.50	9.50	9.00	9.00	8.00	7.00		9.00
Vegetated Filter Strip	10 - 20	5.0			10.00	10.00	9.50	9.50	9.00	7.00	8.50	8.50	8.00	8.00	7.00	6.00	7.00	8.00
Native Vegetation Swale	10 - 20	4.0			10.00	10.00	9.50		8.00	7.00	8.50	8.50	7.00	7.00		5.00	7.00	7.00
Turf Grass Swale	10 - 20	3.0			9.00	9.00	8.50	8.50	7.00	6.00	7.50	7.50	6.00	6.00	5.00		6.00	6.00
Other Systems	50 - 100 [(b)]	3.0			9.00	9.00	8.50	8.50	8.00	6.00	7.50	7.50	7.00	7.00	7.00	6.00	4.00	6.00
Extended Dry Detention Basin	20 - 50	4.0				10.00							8.00	8.00	7.00	6.00		

Note:

a Blank cells indicate BMP combinations that are either infeasible or highly unlikely.

b **Bold** cells indicate feasible treatment train combinations that would reduce the overall VR.

c Additional BMPs may be added using the formula above, provided that the sum of the A and D values (Table 3) do not exceed their respective maximum values, and only the C value

4.4 ADDITIONAL PRACTICES FOR STORMWATER "HOT SPOTS"

Some land uses contribute greater concentrations of hydrocarbons, metals, and other pollutants. They are called "hot spots" and may require additional measures to manage the quality of their runoff (Claytor and Schueler 1996). The final step in creating a water quality protection package is to determine whether the development is a hot spot, and, if so, to specify additional management practices or constraints on the use of some BMPs (such as avoiding infiltration practices that may contribute to groundwater pollution). Appendix B includes management practices for the following land uses (adapted from the City of Portland, Oregon [2002]):

- Fuel Dispensing Facilities
- Aboveground Storage of Liquid Materials
- Solid Waste Storage Areas, Containers, and Trash Compactors
- Exterior Storage of Bulk Materials
- Long-term vehicle storage areas
- Material Transfer Areas and Loading Docks
- Equipment and/or Vehicle Washing Facilities
- Covered Vehicle Parking Areas
- Kennels and Veterinary Clinics
- High-Use Vehicle and Equipment Traffic Areas, Parking, and Vehicle Storage.

WORKSHEET 1: REQUIRED LEVEL OF SERVICE - UNDEVELOPED SITE

Project: By: Date:
Location: Checked: Date:

1. Runoff Curve Number

A. Predevelopment CN

Cover Description	Soil HSG	CN from Table 1	Area (ac.)	Product of CN x Area
		Totals:		

Area-Weighted CN = total product/total area = [ ] (Round to integer)

B. Postdevelopment CN

Cover Description	Soil HSG[1]	CN from Table 1	Area (ac.)	Product of CN x Area
		Totals:		

[1] Postdevelopment CN is one HSG higher for all cover types except preserved vegetation, absent documentation showing how postdevelopment soil structure will be preserved.

Area-Weighted CN = total product/total area = [ ] (Round to integer)

C. Level of Service (LS) Calculation

Predevelopment CN: [ ]

Postdevelopment CN: [ ]

Difference: [ ]

LS Required (see scale at right): [ ]

Change in CN	LS
17+	8
7 to 16	7
4 to 6	6
1 to 3	5
0	4
-7 to -1	3
-8 to -17	2
-18 to -21	1
-22 -	0

WORKSHEET 1A: REQUIRED LEVEL OF SERVICE - DEVELOPED SITE

Project: By: Date:

Location: Checked: Date:

1. Required Treatment Area

A. Total Area Disturbed by Redevelopment Activity (ac.)

Disturbed Area Description	Acres
"1A" Total:	

B. Existing Impervious Area Inside Disturbed Area (ac.)

Existing Impervious Area Description	Acres
"1B" Total:	

C Required Treatment Area (ac.)

"1A" Total Less "1B" Total "1C" [ ]

2. Percent Impervious in Postdevelopment Condition and Level of Service (LS)

A. Total Postdevelopment Impervious Area Inside Disturbed Area (ac.)

Postdevelopment Impervious Area Description	Acres
"2A" Total:	

B. Existing Impervious Area Inside Disturbed Area (ac.)

"1B" Total: [ ]

C. Net Increase in Impervious Area (ac.)

"2A" Total Less "1B" Total "2C" [ ]

D. Percent Impervious

Net Increase in Impervious Area / Required Treatment Area

"2C"/"1C" x 100 [ ] (Round to Integer)

E. Level of Service

Use Percent Impervious to Enter Table XX **LS =** [ ]

3. Minimum Required Total Value Rating of BMP Package

Total Value Rating = LS x Required Treatment Area **VR =** [ ]

WORKSHEET 2: DEVELOP MITIGATION PACKAGE(S) THAT MEET THE REQUIRED LS

Project: By: Date:
Location: Checked: Date:
Sheet __ of __

1. Required LS (New Development, Wksht 1) or Total VR (Redevelopment, Wksht 1A): [ ]

Note: Various BMPs may alter CN of proposed development, and LS; recalculate both if applicable.

2. Proposed BMP Option Package No. ___

Cover/BMP Description	Treatment Area	VR from Table 4.4 or 4.6[1]	Product of VR x Area
Total[2]:		**Total:**	
		***Weighted VR:**	= total product/total a

1 VR calculated for final BMP only in Treatment Train.
2 Total treatment area cannot exceed 100 percent of the actual site area.
* Blank In Redevelopment

Meets required LS (Yes/No)? [ ] (If No, or if additional options are being tested, proceed below.)

3. Proposed BMP Option Package No. ___

Cover/BMP Description	Treatment Area	VR from Table 4.4 or 4.6[1]	Product of VR x Area
Total[2]:		**Total:**	
		***Weighted VR:**	= total product/total a

1 VR calculated for final BMP only in Treatment Train.
2 Total treatment area cannot exceed 100 percent of the actual site area.
* Blank In Redevelopment

Meets required LS (Yes/No)? [ ] (If No, or if additional options are being tested, move to next sheet.)

WORKSHEET 1: REQUIRED LEVEL OF SERVICE - UNDEVELOPED SITE

Project: ***BMP Manual Example No. 1*** By: SAS Date: 11/20/07
Location: Bur Oak, Missouri Checked: Date:

1. Runoff Curve Number

A. Predevelopment CN

Cover Description	Soil HSG	CN from Table 1	Area (ac.)	Product of CN x Area
Woods/grass, good	B	55	14.00	770
Straight Row Crop	B	78	20.38	1589
Straight Row Crop	C	85	30.56	2598
Straight Row Crop	D	89	30.56	2720
		Totals:	95.50	7677

Area-Weighted CN = total product/total area = 80 (Round to integer)

B. Postdevelopment CN

Cover Description	Soil HSG[1]	CN from Table 1	Area (ac.)	Product of CN x Area
Woods/grass, good	B	55	14.00	770
Streets	NA	98	19.51	1912
Residential, 1/3-acre	C	81	15.50	1255
Residential, 1/3-acre	D	86	46.49	3998
		Totals:	95.50	7936

[1] Postdevelopment CN is one HSG higher for all cover types except preserved vegetation, absent documentation showing how postdevelopment soil structure will be preserved.

Area-Weighted CN = total product/total area = 83 (Round to integer)

C. Level of Service (LS) Calculation

Predevelopment CN:	80
Postdevelopment CN:	83
Difference:	3
LS Required (see scale at right):	5

Change in CN	LS
17+	8
7 to 16	7
4 to 6	6
1 to 3	5
0	4
-7 to -1	3
-8 to -17	2
-18 to -21	1
-22 -	0

WORKSHEET 1: REQUIRED LEVEL OF SERVICE - UNDEVELOPED SITE

(Recalculated for BMP Option Package No. 2 with more preserved native vegetation)

Project: ***BMP Manual Example No. 1*** By: SAS Date: 11/20/07

Location: Bur Oak, Missouri Checked: Date:

1. Runoff Curve Number

A. Predevelopment CN

Cover Description	Soil HSG	CN from Table 1	Area (ac.)	Product of CN x Area
Woods/grass, good	B	55	14.00	770
Straight Row Crop	B	78	20.38	1589
Straight Row Crop	C	85	30.56	2598
Straight Row Crop	D	89	30.56	2720
		Totals:	95.50	7677

Area-Weighted CN = total product/total area = **80** (Round to integer)

B. Postdevelopment CN

Cover Description	Soil HSG[1]	CN from Table 1	Area (ac.)	Product of CN x Area
Woods/grass, good	B	55	***16.00***	880
Streets	NA	98	19.51	1912
Residential, 1/3-acre	C	81	15.00	1215
Residential, 1/3-acre	D	86	44.99	3869
				0
		Totals:	95.50	7876

[1] Postdevelopment CN is one HSG higher for all cover types except preserved vegetation, absent documentation showing how postdevelopment soil structure will be preserved.

Area-Weighted CN = total product/total area = **82** (Round to integer)

C. Level of Service (LS) Calculation

Predevelopment CN:	80
Postdevelopment CN:	***82***
Difference:	2
LS Required (see scale at right):	**5**

Note: CN reduction from original plan not enough to reduce LS in this case.

Change in CN	LS
17+	8
7 to 16	7
4 to 6	6
1 to 3	5
0	4
-7 to -1	3
-8 to -17	2
-18 to -21	1
-22 -	0

WORKSHEET 2: DEVELOP MITIGATION PACKAGE(S) THAT MEET THE REQUIRED LS

Project: ***BMP Manual Example No. 1*** By: SAS Date: 11/20/07
Location: Bur Oak, Missouri Checked: Date:
Sheet _1_ of _2_

1. Required LS (from Table 1 or 1A or Worksheet 1 or 1A, as appropriate): 5

Note: Various BMPs may alter CN of proposed development, and LS; recalculate both if applicable.

2. Proposed BMP Option Package No. _1__

Cover/BMP Description	Treatment Area	VR from Table 5 or 6[1]	Product of VR x Area	***Notes:***
Preserved native vegetation	14.00	9.25	129.50	***(Subtract from site total)***
Streets	19.51	0.00	0.00	***(Subtract from site total)***
Houses/driveways	15.50	0.00	0.00	***(25% of remaining site)***
Turf lawn	46.49	0.00	0.00	***(75% of remaining site***
Total[2]:	95.50	**Total:**	129.50	
		Weighted VR:	1.36	= total product/total area

[1] VR calculated for final BMP only in Treatment Train.
[2] Total treatment area cannot exceed 100 percent of the actual site area.

Meets required LS (Yes/No)? NO (If No, or if additional options are being tested, proceed below.)

3. Proposed BMP Option Package No. _2_

Cover/BMP Description	Treatment Area	VR from Table 5 or 6[1]	Product of VR x Area	
Preserved native vegetation	16.00	9.25	148.00	***[Note: 6 lots lost]***
Streets with bio-swales	19.51	6.50	126.82	
Houses w/rain gardens	13.00	9.00	117.00	***[Note: Maintain rain***
Turf lawn	22.24	0.00	0.00	***gardens through covenants***
Turf lawn/driveways to bioswales	24.75	6.50	160.88	***or drainage easements?]***
Total[2]:	95.50	**Total:**	552.69	
		Weighted VR:	5.79	= total product/total area

[1] VR calculated for final BMP only in Treatment Train.
[2] Total treatment area cannot exceed 100 percent of the actual site area.

Meets required LS (Yes/No)? YES (If No, or if additional options are being tested, move to next sheet.)

**** Do not recalculate CN based on restored soils unless a single builder controls the site and guarantees proper restoration.***

WORKSHEET 2: DEVELOP MITIGATION PACKAGE(S) THAT MEET THE REQUIRED LS

Project: ***BMP Manual Example No. 1*** By: SAS Date: 11/20/07
Location: Bur Oak, Missouri Checked: Date:
Sheet _2_ of _2_

1. Required LS (from Table 1 or 1A or Worksheet 1 or 1A, as appropriate): 5

Note: Various BMPs may alter CN of proposed development, and LS; recalculate both if applicable.

2. Proposed BMP Option Package No. _3_

Cover/BMP Description	Treatment Area	VR from Table 5 or 6[1]	Product of VR x Area
Preserved native vegetation	14.00	9.25	129.50
Streets	19.51	0.00	0.00
Houses/driveways	15.50	0.00	0.00
Native grass lawn*	46.49	9.25	430.06
Total[2]:	95.50	**Total:**	559.56
		Weighted VR:	5.86

[Note: Maintain native lawns through covenants?]

Weighted VR = total product/total area

[1] VR calculated for final BMP only in Treatment Train.
[2] Total treatment area cannot exceed 100 percent of the actual site area.

Meets required LS (Yes/No)? YES (If No, or if additional options are being tested, proceed below.)

3. Proposed BMP Option Package No. _4_

Cover/BMP Description	Treatment Area	VR from Table 5 or 6[1]	Product of VR x Area
Total[2]:		**Total:**	
		Weighted VR:	

Weighted VR = total product/total area

[1] VR calculated for final BMP only in Treatment Train.
[2] Total treatment area cannot exceed 100 percent of the actual site area.

Meets required LS (Yes/No)? (If No, or if additional options are being tested, move to next sheet.)

**** Do not recalculate CN based on restored soils unless a single builder controls the site and guarantees proper restoration.***

Figure 4.3 - Soils and Development summary

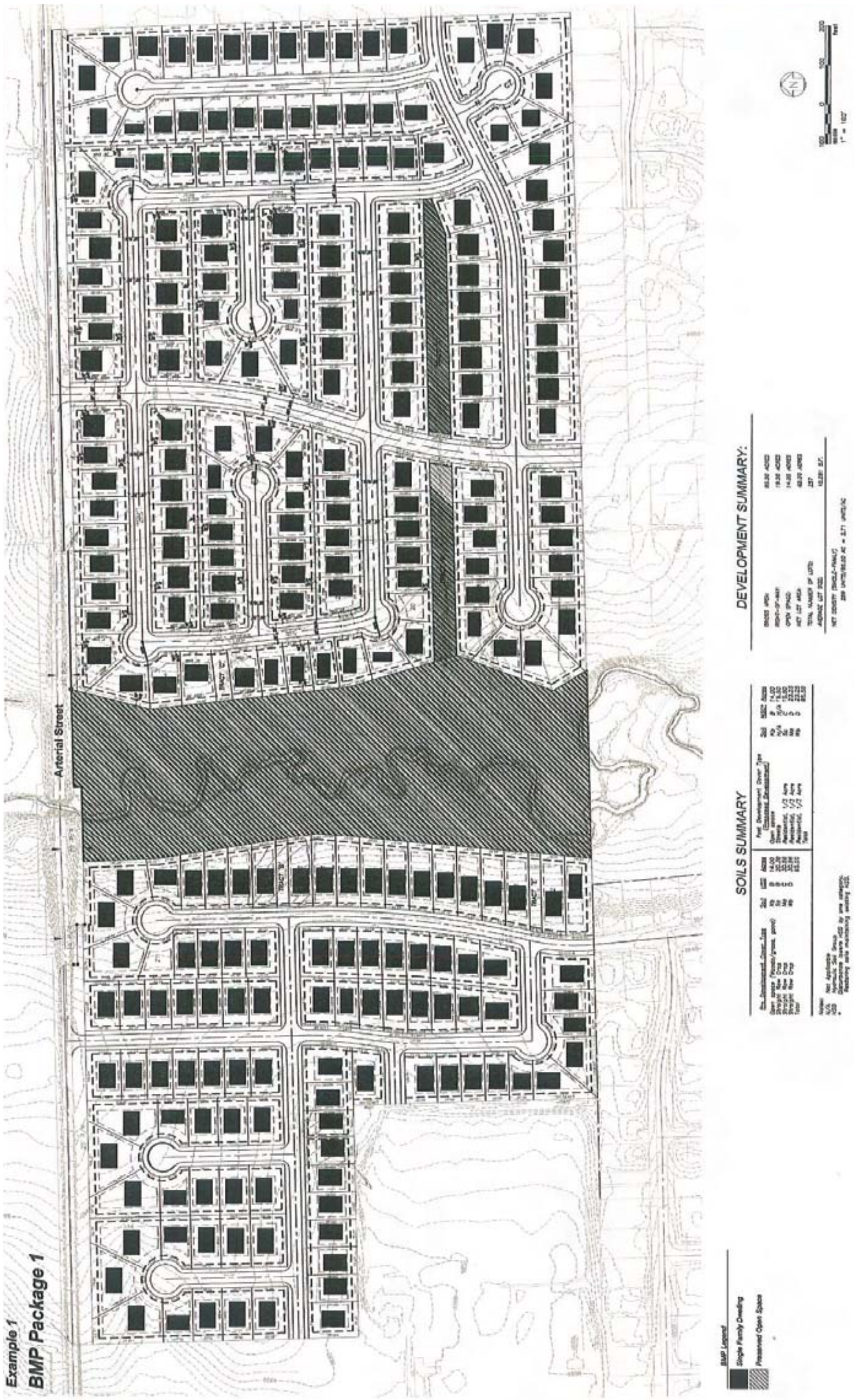


Figure 4.4 - Example 1 BMP Package 1

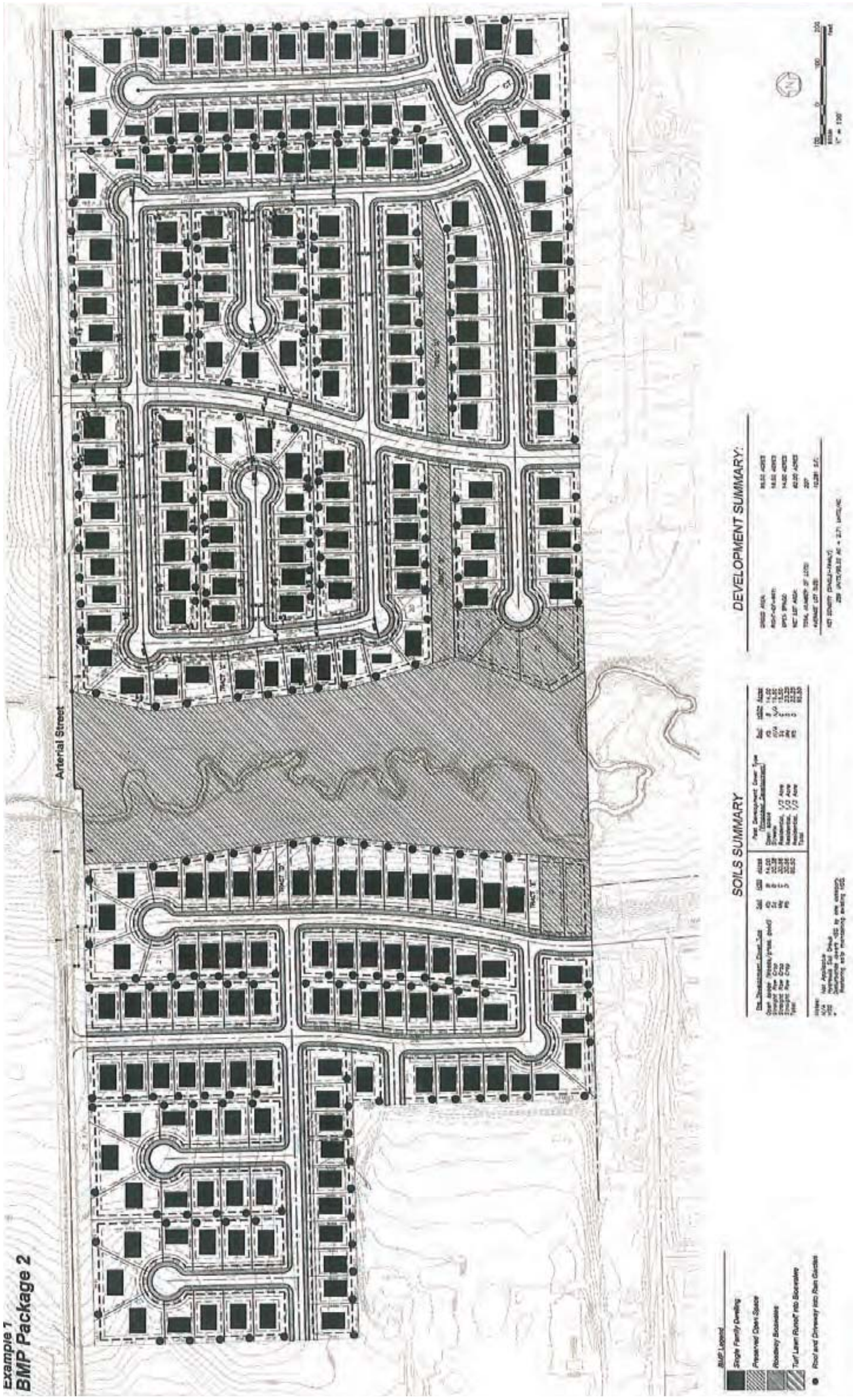


Figure 4.5 - Example 1 BMP Package 2

Figure 4.6 - Example 1 BMP Package 3

WORKSHEET 1: REQUIRED LEVEL OF SERVICE - UNDEVELOPED SITE

Project: ***BMP Manual Example No. 2*** By: SAS Date: 11/20/07
Location: Smallville, Kansas Checked: Date:

1. Runoff Curve Number

A. Predevelopment CN

Cover Description	Soil HSG	CN from Table 1	Area (ac.)	Product of CN x Area
Pasture, good	B	61	51.00	3111
		Totals:	51.00	3111

Area-Weighted CN = total product/total area = 61 (Round to integer)

B. Postdevelopment CN

Cover Description	Soil HSG[1]	CN from Table 1	Area (ac.)	Product of CN x Area
Buildings	NA	98	10.00	980
Parking	NA	98	22.00	2156
Turf grass lawn	C	74	16.00	1184
Pond	NA	98	3.00	294
		Totals:	51.00	4614

[1] Postdevelopment CN is one HSG higher for all cover types except preserved vegetation, absent documentation showing how postdevelopment soil structure will be preserved.

Area-Weighted CN = total product/total area = 90 (Round to integer)

C. Level of Service (LS) Calculation

Predevelopment CN:	61
Postdevelopment CN:	90
Difference:	29
LS Required (see scale at right):	8

Change in CN	LS
17+	8
7 to 16	7
4 to 6	6
1 to 3	5
0	4
-7 to -1	3
-8 to -17	2
-18 to -21	1
-22 -	0

WORKSHEET 1: REQUIRED LEVEL OF SERVICE - UNDEVELOPED SITE

(Recalculated for BMP Option Package No. 3 with native grass lawns)

Project: ***BMP Manual Example No. 2*** By: SAS Date: 11/20/07

Location: Smallville, Kansas Checked: Date:

1. Runoff Curve Number

A. Predevelopment CN

Cover Description	Soil HSG	CN from Table 1	Area (ac.)	Product of CN x Area
Pasture, good	B	61	51.00	3111
		Totals:	51.00	3111

Area-Weighted CN = total product/total area = 61 (Round to integer)

B. Postdevelopment CN

Cover Description	Soil HSG[1]	CN from Table 1	Area (ac.)	Product of CN x Area
Buildings	NA	98	10.00	980
Parking	NA	98	22.00	2156
Native grass	***B***	***58***	16.00	928
Pond	NA	98	3.00	294
		Totals:	51.00	4358

Group B only <u>if</u> topsoil is preserved according to Appendix A.

[1] Postdevelopment CN is one HSG higher for all cover types except preserved vegetation, absent documentation showing how postdevelopment soil structure will be preserved.

Area-Weighted CN = total product/total area = 85 (Round to integer)

C. Level of Service (LS) Calculation

Predevelopment CN: 61

Postdevelopment CN: ***85***

Difference: 24

LS Required (see scale at right): 8

Note: CN reduction from original plan not enough to reduce LS in this case.

Change in CN	LS
17+	8
7 to 16	7
4 to 6	6
1 to 3	5
0	4
-7 to -1	3
-8 to -17	2
-18 to -21	1
-22 -	0

WORKSHEET 2: DEVELOP MITIGATION PACKAGE(S) THAT MEET THE REQUIRED LS

Project: ***BMP Manual Example No. 2*** By: SAS Date: 11/20/07
Location: Smallville, Kansas Checked: Date:
Sheet _1_ of _2_

1. Required LS (from Table 1 or 1A or Worksheet 1 or 1A, as appropriate): 8

Note: Various BMPs may alter CN of proposed development and LS; recalculate both if applicable.

2. Proposed BMP Option Package No. _1_

Cover/BMP Description	Treatment Area	VR from Table 5 or 6[1]	Product of VR x Area
Building with extended wet det.	10.00	5.00	50.00
Parking with extended wet det.	22.00	5.00	110.00
Turf lawn with extended wet det.	16.00	5.00	80.00
Extended wet detention	3.00	5.00	15.00
Total[2]:	51.00	**Total:**	255.00
		Weighted VR:	5.00

= total product/total area

[1] VR calculated for final BMP only in Treatment Train.
[2] Total treatment area cannot exceed 100 percent of the actual site area.

Meets required LS (Yes/No)? NO (If No, or if additional options are being tested, proceed below.)

3. Proposed BMP Option Package No. _2_

Cover/BMP Description	Treatment Area	VR from Table 5 or 6[1]	Product of VR x Area
Building with bioretention	10.00	X	0.00
Parking with perimeter sand filter	22.00	X	0.00
Turf lawn with ED wetland	16.00	7.00	112.00
ED wetland	3.00	7.00	21.00
Bioretention + ED wetland(t. train)	10.00	9.50	95.00 **(TT = Table 6)**
Sand filter + ED wetland (t. train)	22.00	8.00	176.00
Total[2]:	51.00	**Total:**	404.00
		Weighted VR:	7.92

= total product/total area

[1] VR calculated for final BMP only in Treatment Train.
[2] Total treatment area cannot exceed 100 percent of the actual site area.

Meets required LS (Yes/No)? NO (If No, or if additional options are being tested, move to next sheet.)

WORKSHEET 2: DEVELOP MITIGATION PACKAGE(S) THAT MEET THE REQUIRED LS

Project: ***BMP Manual Example No. 2*** By: SAS Date: 11/20/07
Location: Smallville, Kansas Checked: Date:
Sheet _2_ of _2_

1. Required LS (from Table 1 or 1A or Worksheet 1 or 1A, as appropriate): 8

Note: Various BMPs may alter CN of proposed development and LS; recalculate both if applicable.

2. Proposed BMP Option Package No. _3_

Cover/BMP Description	Treatment Area	VR from Table 5 or 6[1]	Product of VR x Area	
Building with ED wetland	10.00	7.00	70.00	
Parking with ED wetland	22.00	7.00	154.00	
Native lawn*	16.00		0.00	
ED wetland	3.00	7.00	21.00	
Native lawn +ED wetland (t. train)	16.00	10.25	164.00	**(TT = Table 6)**
Total[2]:	51.00	**Total:**	409.00	
		Weighted VR:	8.02	= total product/total area

1 VR calculated for final BMP only in Treatment Train.
2 Total treatment area cannot exceed 100 percent of the actual site area.

Meets required LS (Yes/No)? YES (If No, or if additional options are being tested, proceed below.)

3. Proposed BMP Option Package No. _4_

Cover/BMP Description	Treatment Area	VR from Table 5 or 6[1]	Product of VR x Area	
Building with bio-swales	10.00		0.00	
Parking with bio-swales	22.00		0.00	
Turf lawn with ED wetland	16.00	7.00	112.00	
ED wetland	3.00	7.00	21.00	
Bio-swale + ED wetland (t. train)	32.00	10.50	336.00	**(TT = Table 6)**
			0.00	
Total[2]:	51.00	**Total:**	469.00	
		Weighted VR:	9.20	= total product/total area

1 VR calculated for final BMP only in Treatment Train.
2 Total treatment area cannot exceed 100 percent of the actual site area.

Meets required LS (Yes/No)? YES (If No, or if additional options are being tested, move to next sheet.)

**** Recalculated CN based on restored soils and native vegetation. See alternate Worksheet 1, attached.***

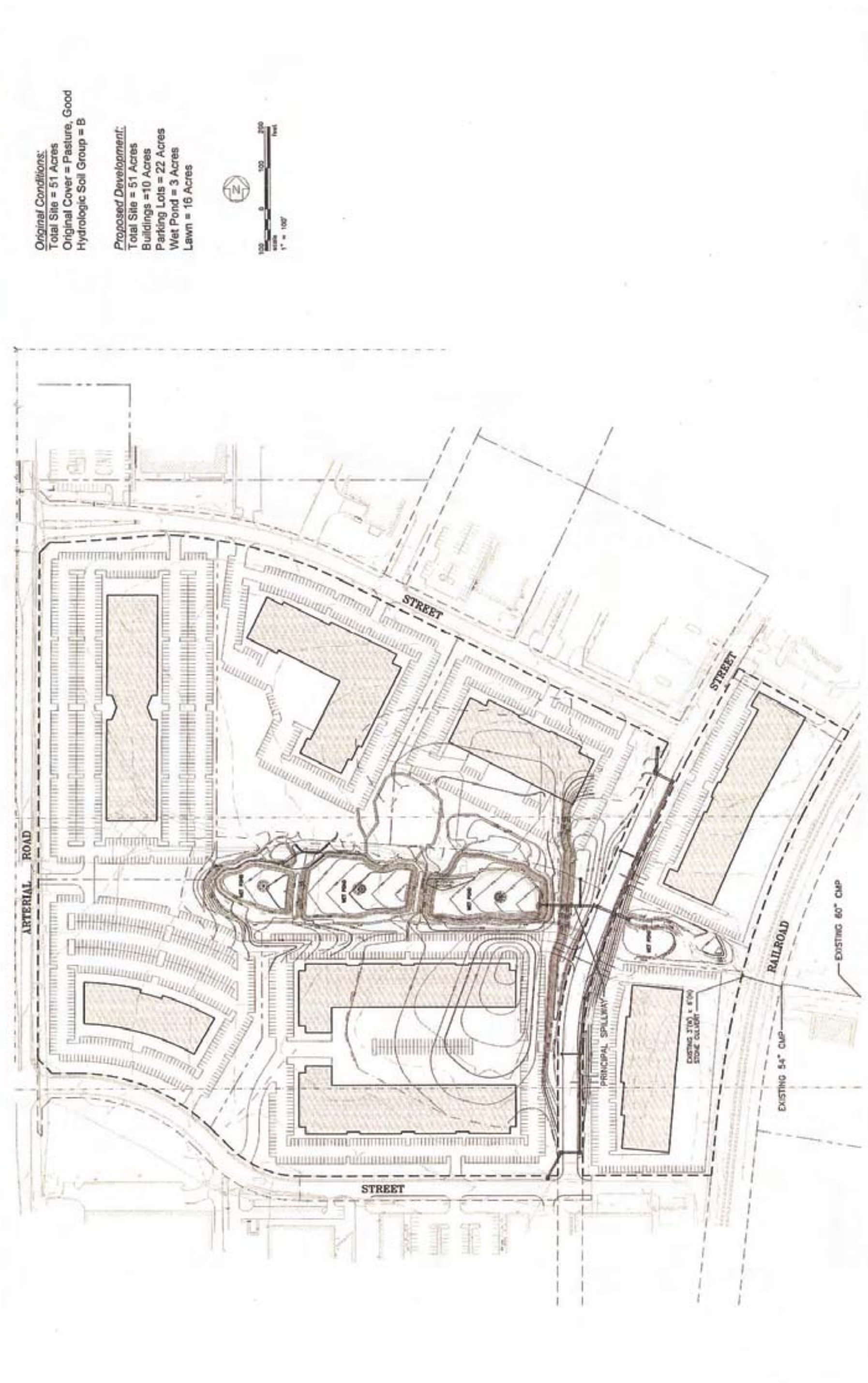


Figure 4.7 - Proposed Development

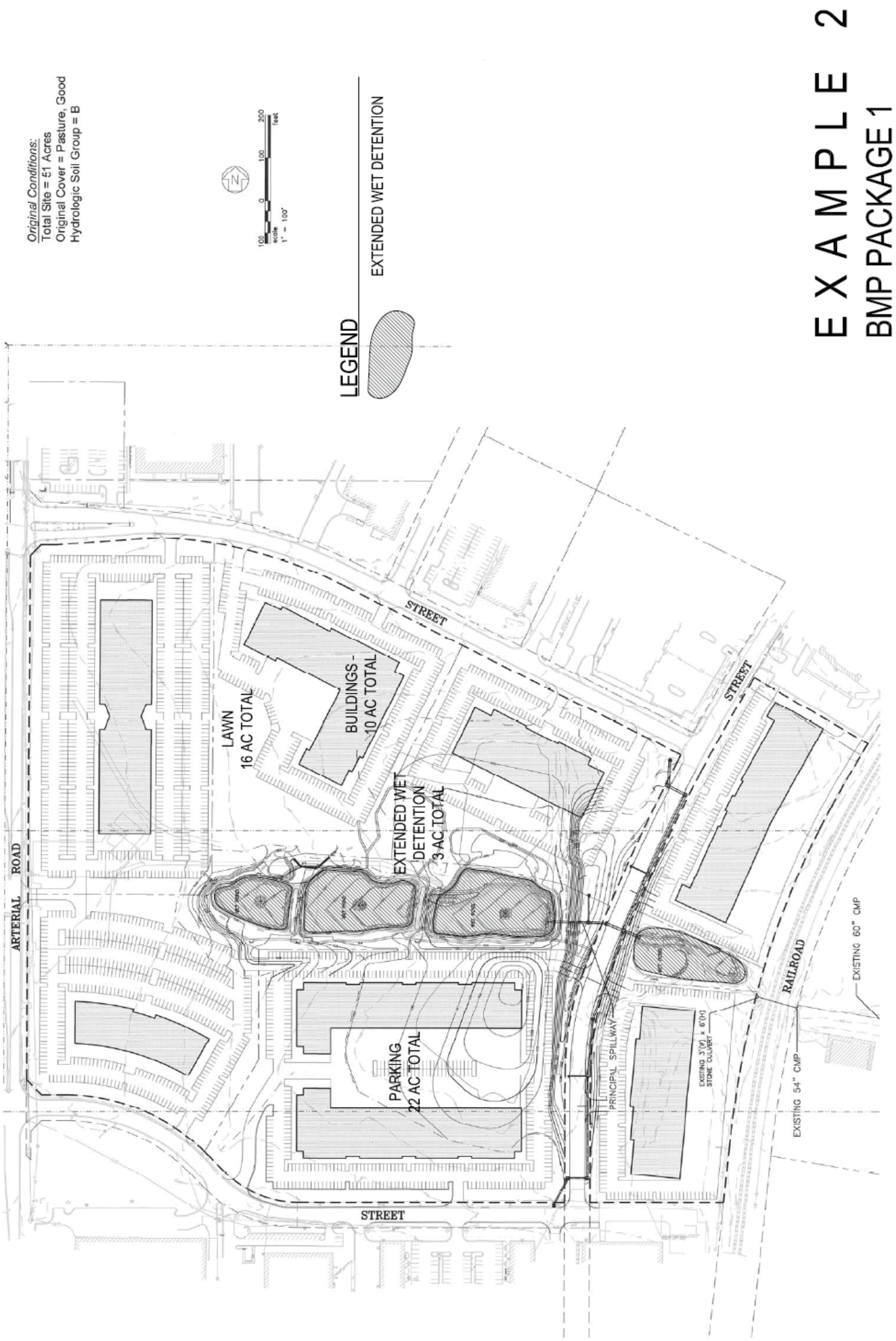


Figure 4.8 - Example 2 BMP Package 1

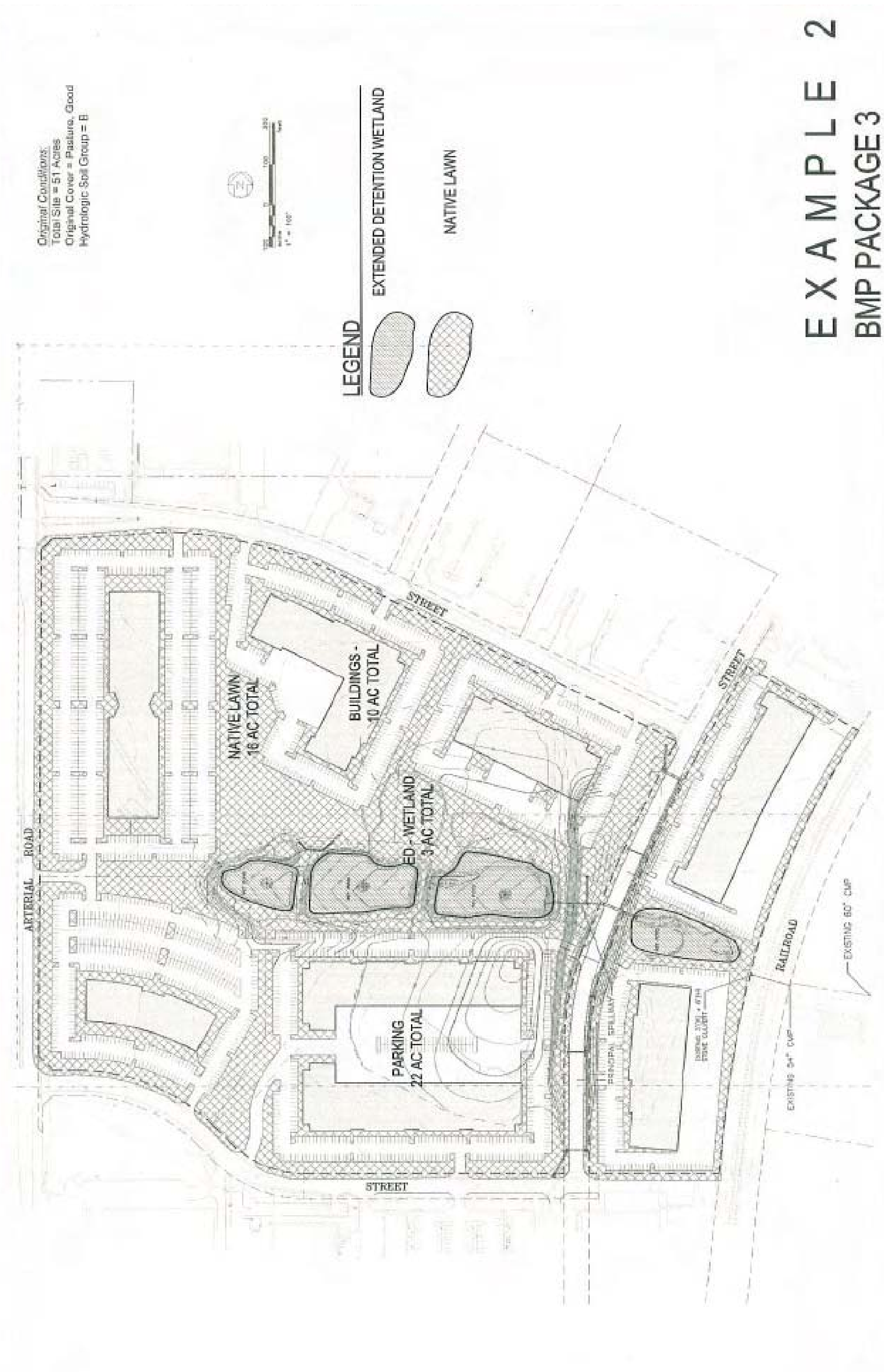


Figure 4.9 - Example 2 BMP Package 3

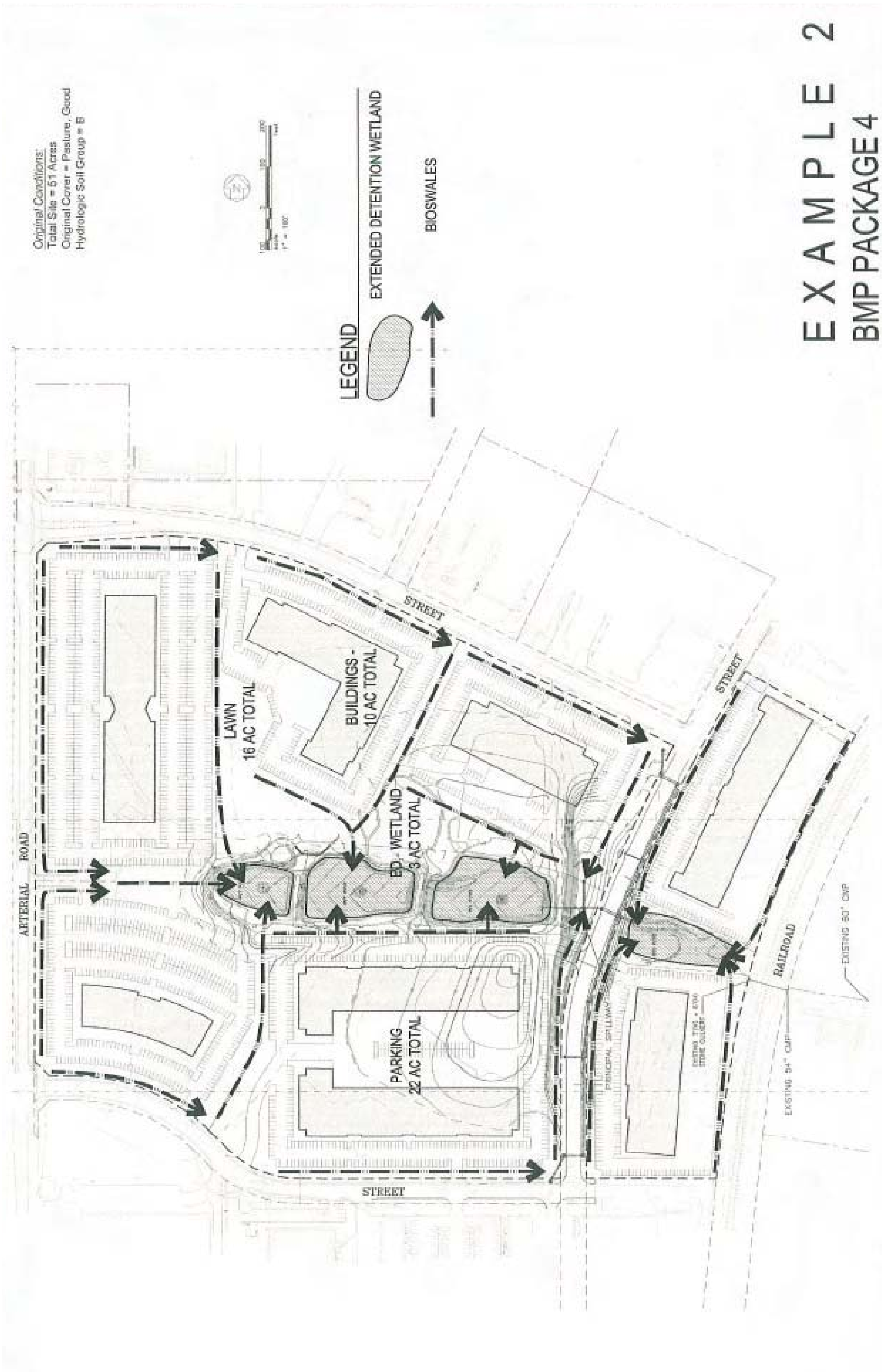


Figure 4.10 - Example 2 BMP Package 4

WORKSHEET 1A: REQUIRED LEVEL OF SERVICE - DEVELOPED SITE

Project:	***BMP Manual Example No. 3***	By:	ABC	Date:	4/1/2009
Location:	Townsville, Missouri	Checked:		Date:	

1. Required Treatment Area

A. Total Area Disturbed by Redevelopment Activity (ac.)

Disturbed Area Description	Acres
Building (Includes border around building footprint)	0.80
Parking (Includes 10-foot border around parking area)	2.85
Access Drives (Includes 15-foot border each side of access drive)	0.59
Staging and Grading Areas	0.82
"1A" Total:	5.06

B. Existing Impervious Area Inside Disturbed Area (ac.)

Existing Impervious Area Description	Acres
Northeast buidling and access road	0.17
South building and access road	0.19
"1B" Total:	0.36

C Required Treatment Area (ac.)

"1A" Total Less "1B" Total "1C" **4.70**

2. Percent Impervious in Postdevelopment Condition and Level of Service (LS)

A. Total Postdevelopment Impervious Area Inside Disturbed Area (

Postdevelopment Impervious Area Description	Acres
Building	0.43
Parking	2.02
Access Drives	0.28
"2A" Total:	2.73

B. Existing Impervious Area Inside Disturbed Area (ac.)

"1B" Total: 0.36

C. Net Increase in Impervious Area (ac.)

"2A" Total Less "1B" Total "2C" 2.37

D. Percent Impervious

Net Increase in Impervious Area / Required Treatment Area

"2C"/"1C" x 100 58% (Round to Integer)

E. Level of Service

Use Percent Impervious to Enter Table XX **LS = 5.8**

3. Minimum Required Total Value Rating of BMP Package

Total Value Rating = LS x Required Treatment Area **VR = 27.26**

WORKSHEET 2: DEVELOP MITIGATION PACKAGES(S) THAT MEET THE REQUIRED LS

Project:	***BMP Manual Example No. 3***	By:	ABC	Date:	4/1/2009
Location:	Townsville, Missouri	Checked:		Date:	
Sheet:	1 of _1__				

1. **Required LS (New Dev., Wksht 1) or Total VR (Redev., Wksht 1A):** 27.26

Note: Various BMPs may alter CN of proposed development, and LS; recalculate both if applicable.

2. **Proposed BMP Option Package No.** **1**

Cover/BMP Description	Treatment Area	VR from Table 4.4 or 4.6[1]	Product of VR x Area
Building into bioretention	**0.43**	**8.50**	**3.66**
Access drives	**0.28**	**0.00**	**0.00**
Lawn	**0.30**	**0.00**	**0.00**
Parking/lawn into native veg. swale	**2.60**	**4.00**	**10.40**
Native vegetation - reestablished	**1.25**	**9.25**	**11.56**
Bioretention	**0.20**	**8.50**	**1.70**
Total[2]:	**5.06**	**Total:**	**27.32**
		***Weighted VR:**	=total product/total area

[1] VR calculated for final BMP only in Treatment Train

[2] Total treatment area cannot exceed 100 percent of the actual site area

* Blank in redevelopment

Meets required LS (Yes/No)? **YES** (If No, or if additional options are being tested, proceed below.)

3. **Proposed BMP Option Package No.** **2**

Cover/BMP Description	Treatment Area	VR from Table 4.4 or 4.6[1]	Product of VR x Area
Building	**0.43**	**0.00**	**0.00**
Access drives	**0.28**	**0.00**	**0.00**
Lawn	**0.98**	**0.00**	**0.00**
Parking into porous pavement	**2.02**	**7.50**	**15.15**
Native vegetation - reestablished	**1.35**	**9.25**	**12.49**
Total[2]:	**5.06**	**Total:**	**27.64**
		***Weighted VR:**	=total product/total area

[1] VR calculated for final BMP only in Treatment Train

[2] Total treatment area cannot exceed 100 percent of the actual site area

* Blank in redevelopment

Meets required LS (Yes/No)? YES (If No, or if additional options are being tested, move to next sheet.)

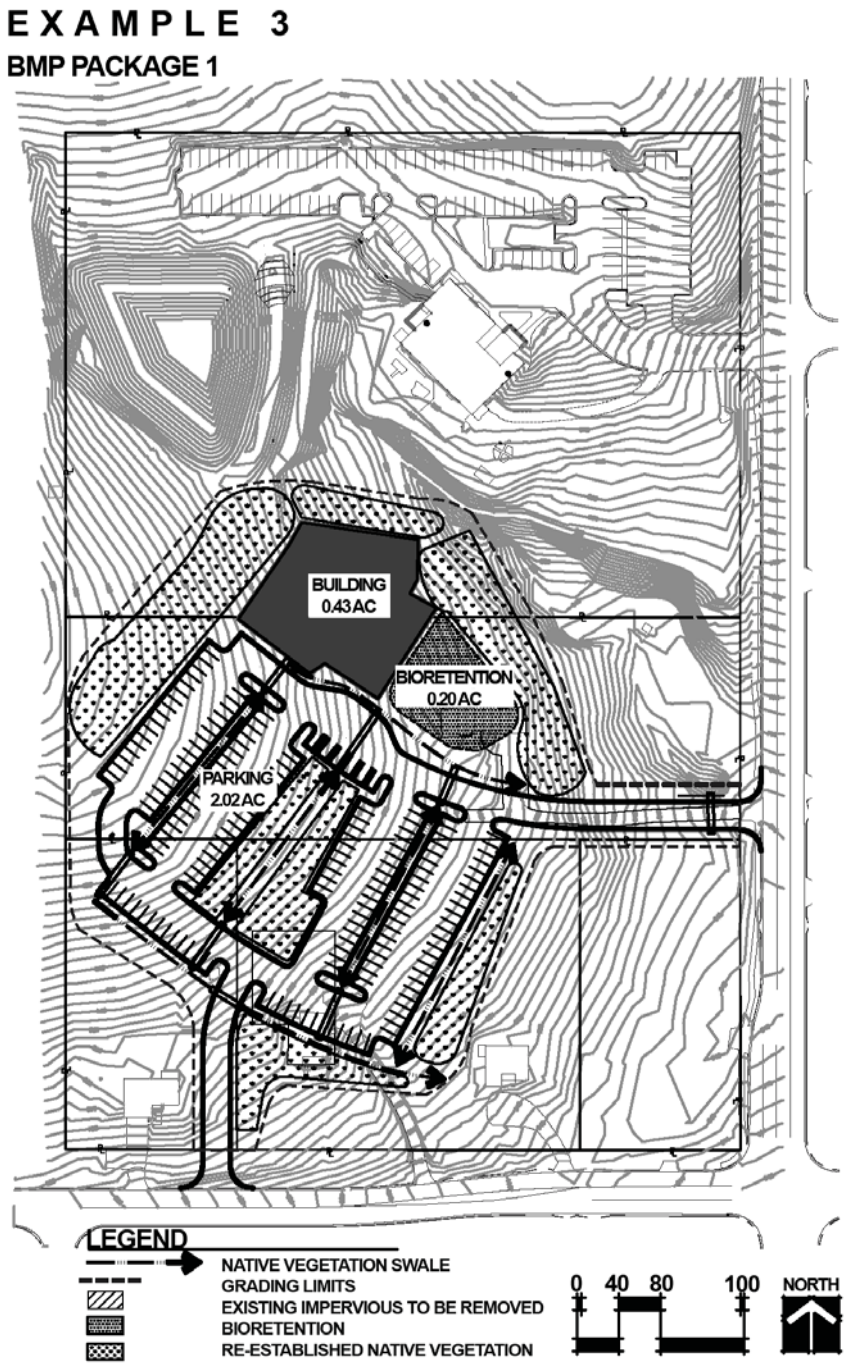


Figure 4.11 - Example 3 BMP Package 1

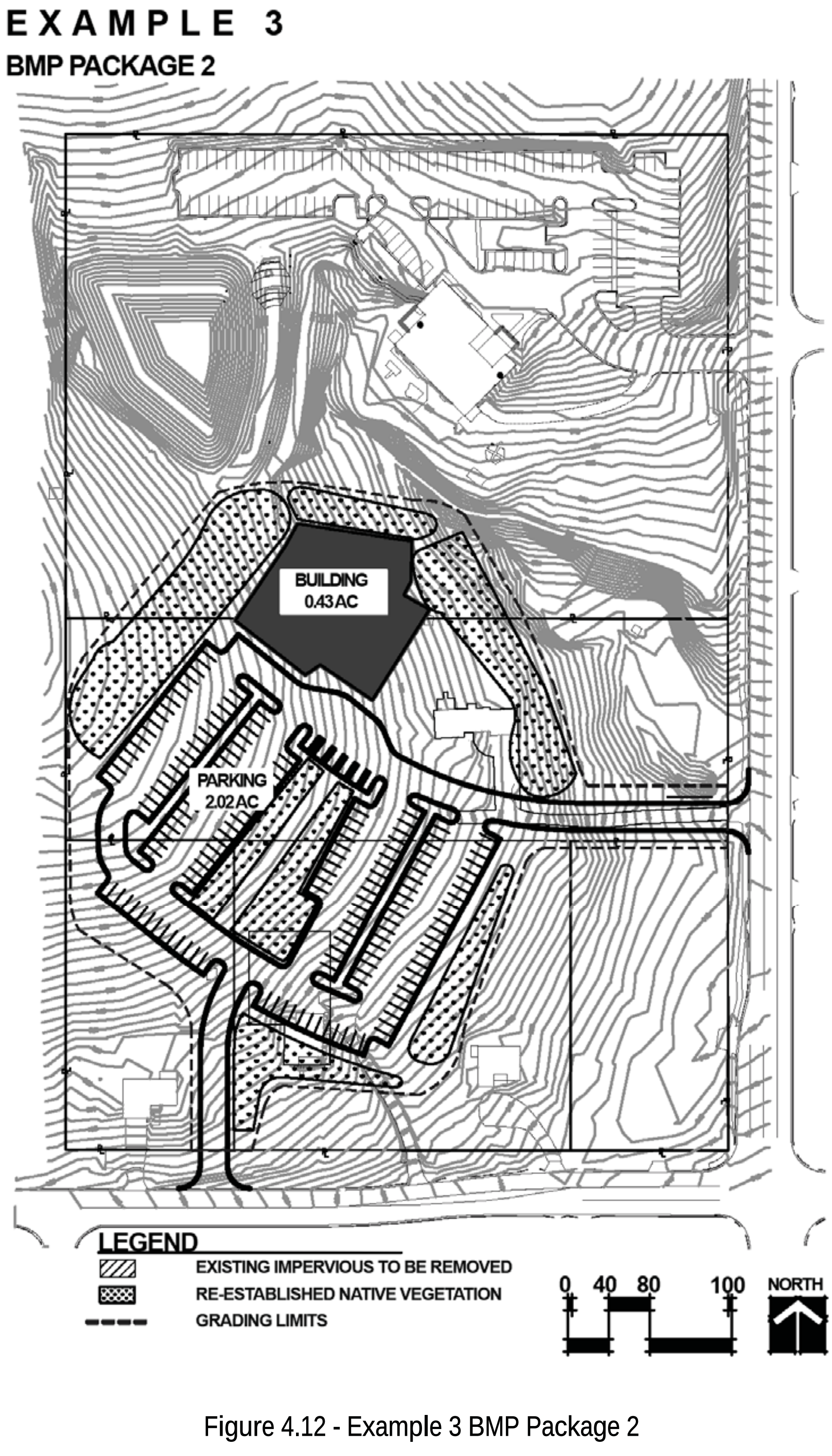


Figure 4.12 - Example 3 BMP Package 2

Section 5

Initial Measures and Minimum Practices

5.0 INITIAL MEASURES AND MINIMUM PRACTICES

The LS Method, described in Section 4.0, is detailed and flexible enough to be applicable for a wide variety of site conditions and development designs. Communities may start with a simplified water quality management program that incorporates a few widely accepted BMPs, however. The minimum program includes:

- Introducing community-wide stream buffer systems through enactment of stream setback ordinances
- Applying soil protection and restoration requirements to residential developments
- Capturing runoff from all impervious surfaces in non-residential developments using bioretention areas
- Discouraging or eliminating direct connections of impervious areas to storm drains.
- Regulating commercial and industrial "hot spots."

Descriptions of these minimum practices follow. (General siting and design guidance are discussed in Sections 7 and 8, and detailed design specifications for each of these measures are included in Section 9. Standard specifications and plans are provided in Appendix A.)

5.1 STREAM BUFFERS

Creating a system of stream buffers is an important first step. The "riparian zone" (the heavily vegetated strip along the fringe of a stream) is an integral part of the stream system. For example, preservation of a 100-foot riparian buffer—only about 5 percent of the land in a typical watershed—can yield disproportionate benefits. This buffer limits development in the floodplain and controls streambank erosion; it removes pollutants from adjacent properties; and it can serve as a greenway park (Haag, Mazzeo, and Schulte 2001). Buffers also provide financial returns to communities—research indicates that a comprehensive system of stream buffers, typically about 5 percent of a community's developable land, may increase adjacent property values by as much as 33 percent (Chesapeake Bay Foundation 1996).

A comprehensive stream setback ordinance restricts development practices and allowed uses in the stream setback zone. This broad zone encompasses a given distance and is typically divided in two to three zones. Zones closest to the stream have the most restrictions. Zones further from the stream have increased flexibility for use. Several local setback ordinances serve as models for the creation of stream setbacks and buffer zones in this region. The U.S. Environmental Protection Agency (EPA) and Johnson County, Kansas, have developed a standard ordinance that cities throughout the region may adopt (Johnson County, Kansas 2001). Stream setbacks and buffers can be based on a set of generic assumptions about streams and developments or (preferably) on actual stream conditions documented through a natural resource inventory; clear and cost-effective stream assessment protocols have been developed and used throughout the MARC region (City of Lenexa, Kansas 2001; Patti Banks Associates). Section 7 provides more information and design guidance for riparian buffer design.

5.2 SOIL PRESERVATION AND RESTORATION

The second measure to protect water quality is a development regulation requiring soil protection and/or restoration in all residential developments. Both stormwater runoff volumes and water quality are heavily influenced by infiltration capacity (USDA 1986; Claytor and Schueler 1996). Urbanization, through increased impervious surfaces and soil compaction, shorten a watershed's response to precipitation by reducing infiltration and decreasing travel time. While impervious surfaces should be limited as much as practical, soil preservation and restoration measures can mitigate the impacts of urbanization by improving the infiltration capacity of soils in vegetated areas, Preserving the soil's capacity to infiltrate precipitation is a relatively inexpensive non-structural measure that can be implemented as a preservation component of the site design. Soil restoration, while a potentially challenging phase of the construction sequence, is another way to improve infiltration.

Soil preservation and restoration efforts are most effective in residential developments due to limited impervious surfaces, typically 12 – 65 percent (USDA 1986). However, even in commercial, office and manufacturing areas, where impervious surfaces make up 72 – 85 percent of the area (USDA 1986), soil structure remains an important factor in producing runoff. Natural infiltration rates to underlying soils are primarily influenced by soil type, soil structure and plant cover. Any preserved area will retain these important characteristics and, thus, the pre-development infiltration capacity.

Any disturbance of a soil profile by mixing native soil profiles, introducing off-site fill materials, and increasing soil compaction can significantly change infiltration characteristics (USDA 1986). Restoring infiltration characteristics of the entire soil profile in residential areas (and other developments) after disturbance will also benefit water quality. Soil restoration requirements can help residential developments maximally infiltrate stormwater for given vegetation and cover types without structural treatment measures. Communities could include this requirement in residential development codes or as part of sediment and erosion control specifications. The requirements can be applied easily to other developments as well. A detailed soil protection and restoration specification is in Section 7.

5.3 BIORETENTION

Stormwater runoff from impervious surfaces in non-residential land uses (commercial, office, and manufacturing) should be treated. These land uses generate more impervious surface, typically 72 – 84+ percent (USDA 1986), than residential developments and, as previously described, this significantly impacts a community's water quality. Most pollutants originate from atmospheric deposition, which results in impervious surfaces being the major source of stormwater pollutants in urban areas (Claytor and Schueler 1996).

Communities can significantly impact their water quality by treating runoff from non-residential impervious surfaces, such as rooftops and parking lots. It is recommend that as part of their development code, communities require treatment of runoff from all new impervious surfaces by using bioretention cells (vegetated depressions designed to collect and treat runoff from the Water Quality Storm through an engineered matrix of soils and plant roots). Effective bioretention cells typically require only about 5 percent of the total impervious area. They are easily designed and planned as part of the site's required open space. In practice, these units are maintained in the same manner as decorative landscaped beds—minimizing maintenance costs and increasing value-added benefits. Implementing this one standardized practice in all developments can minimize design, inspection, and maintenance costs.

Detailed design guidance for bioretention is in Section 8, and standard specifications and plans are in Appendix A.

5.4 ELIMINATE DIRECT CONNECTIONS

Direct connections include downspouts and sump pumps that flow directly onto pavement or that are piped into stormwater inlets. By directing downspouts and sump pumps into rain gardens or other pervious surfaces, increased infiltration will result. This measure requires close attention to site drainage patterns to minimize associated problems such as building or street flooding.

5.5 REGULATE "HOT SPOTS"

Land uses that contribute greater concentrations of hydrocarbons, metals, and other pollutants are called "hot spots" and may require additional measures to manage the quality of their runoff (Claytor and Schueler 1996). Communities should require commercial and industrial hot spots to adopt industry-specific BMPs or should impose local regulations. Appendix B includes management practices for various land uses (adapted from the City of Portland, Oregon [2002]).

Section 6

Hydrology Methods

6.0 HYDROLOGY METHODS

6.1 GENERAL

Sizing BMPs properly is critical to their success. Design detention and retention BMPs to capture and treat the WQv. Design conveyance BMPs to handle peak discharge of the WQv. WQv is defined as the storage needed to capture and treat 90 percent of the average annual stormwater runoff volume. WQv is based on the Water Quality Storm and volumetric runoff coefficient and site area. The Water Quality Storm is defined as the storm event that produces less than or equal to 90 percent volume of all 24-hour storms on an annual basis.

The Water Quality Storm for the Kansas City Metropolitan Area is 1.37 inches (Young and McEnroe 2002).

Two methods can be used to estimate the WQv for a proposed development—the Short-Cut Method and the Small-Storm Hydrology Method.

6.2 SHORT-CUT METHOD

Use the Short-Cut Method (Claytor and Schueler 1996) only for sites with one predominant type of cover and a drainage area less than 10 acres:

WQv = P * Rv

Where:

WQv = Water Quality Volume (inches)

P = Rainfall event in inches (the Water Quality Storm of 1.37 inches or other appropriate amount, with the approval of the city engineer)

Rv = Volumetric runoff coefficient
= 0.05 + 0.009(I)

I = Percent site imperviousness (%)

6.3 SMALL STORM HYDROLOGY METHOD

The Small Storm Hydrology Method (Claytor and Schueler 1996) is based on the volumetric runoff coefficient (Rv), which accounts for specific characteristics of the pervious and impervious surfaces of the drainage catchment. This method may be used for all drainage areas. Rv's used to compute the volume of runoff are identified in Table 6.1. The Small Storm Hydrology Method is:

WQv = P * Weighted Rv

Where:

Weighted Rv = $\sum$(Rv1*Ac1)+(Rv2*Ac2)+…(Rv_i*Ac_i)/Total Acreage

Rv_i = Volumetric runoff coefficient for cover type *i*

Ac_i = Area of cover type *i* (acres)

Total Acreage = Total area of the drainage area (acres)

A reduction factor may be applied to the Rv values for drainage areas with disconnected impervious surfaces. The pervious surface flow path below an impervious area must be at least twice the impervious flow path. The reduction factors are provided in Table 6.2.

TABLE 6.1 Volumetric Coefficients For Urban Runoff for Directly Connected Impervious Areas (Claytor and Schueler 1996)					
Rainfall (inches)	Flat roofs and large unpaved parking lots	Pitched roofs and large impervious areas (large parking lots)	Small impervious areas and narrow streets	Silty soils HSG-B	Clayey soils HSG-C and D
0.75	0.82	0.97	0.66	0.11	0.20
1.00	0.84	0.97	0.70	0.11	0.21
1.25	0.86	0.98	0.74	0.13	0.22
1.37	0.87	0.98	0.75	0.14	0.23
1.50	0.88	0.99	0.77	0.15	0.24

TABLE 6.2 Reduction Factors To Volumetric Runoff Coefficients for Disconnected Impervious Surfaces (Claytor and Schueler 1996)				
Rainfall (inches)	Strip commercial and shopping center	Medium-to-high-density residential with paved alleys	Medium-to-high-density residential without alleys	Low-density residential
0.75	0.99	0.27	0.21	0.20
1.00	0.99	0.38	0.22	0.21
1.25	0.99	0.48	0.22	0.22
1.37	0.99	0.53	0.23	0.23
1.50	0.99	0.59	0.24	0.24

Note:

To use the reduction factors for disconnected impervious surfaces listed above, the impervious area uphill from a pervious area (a cover type that allows stormwater to infiltrate) should be less than one-half the area of the pervious surface, and the flow path through the pervious area should be at least twice the impervious surface flow path. For example, a 10-foot wide sidewalk would be a “disconnected impervious surface” if separated from the conveyance system by a 20-foot grassed strip or other pervious cover.

6.4 RATIONAL METHOD

To size a conveyance BMP correctly, calculate the peak discharge for the Water Quality Storm using the Rational Method.

The Rational Method is defined as follows:

$$Q = K \cdot C \cdot i \cdot A$$

Where:

Q = Peak rate of runoff (cfs)

C = Runoff Coefficient

$C = 0.3 + 0.6 \cdot I$ where I is percent impervious divided by 100

i = Rainfall intensity from **Table 6.3** at the calculated time of concentration (inches/hr)

K = Dimensionless coefficient to account for antecedent precipitation

K = 1 (Water Quality Storm which is 90% Event)

TABLE 6.3
Rainfall Intensity for Water Quality
Rainfall Event (1.37 inches)

Time of Conc. (min)	i (in/hr)
5	1.90
6	1.90
7	1.86
8	1.80
9	1.74
10	1.68
11	1.63
12	1.57
13	1.52
14	1.47
15	1.42
> 15	1.40

The rainfall rates shown in Table 6.3 pertain to the Kansas City Metropolitan area.

6.4.1 Determine Time of Concentration (Tc)

(Source: Section 5602.7 of APWA 5600, November 2005)

Time of concentration is equal to the overland flow time to the most upstream inlet or other point of entry to an enclosed system or channel plus the time for flow to travel in the enclosed system or channel to the point of consideration. The Time of Concentration (Tc) is defined as:

$T_c = T_I + T_T$

Where:

Tc = Time of Concentration (min)

T_I = Overland flow time to the most upstream inlet or point of entry (min)

T_T = Travel time in an enclosed or channel (min)

6.4.2 Overland Flow Time (T_I):

The overland flow time to the most upstream inlet or other point of entry shall be calculated by the following formula or other method approved by the reviewing agency but shall not be greater than 15 minutes.

$T_I = 1.8 \cdot (1.1 - C) \cdot D^{1/2} / S^{1/3}$

Where

T_I = Overland flow time to the most upstream inlet or point of entry (min)

C = Rational Method Runoff Coefficient

D = Overland flow distance parallel to slope (ft)

D <= 100 (100 feet shall be the maximum distance for overland flow)

S = Slope of overland flow path (%)

6.4.3 Travel Time in an Enclosed System or Channel (T_T):

The time for flow to travel in an enclosed system or in channel is defined as concentrated flow and shall be calculated by the following formula or other method approved by the reviewing agency. The travel time (T_T) shall be calculated as the length of travel in the channelized system divided by the velocity of flow:

$$T_T = D_c / V$$

Where

T_T = Channelized travel time (min)

D_c = Channelized flow distance (ft)

V = Velocity of flow (ft/min)

Velocity shall be calculated by Manning's equation or from Table 6.4 when the channelized flow is in an unimproved channel.

TABLE 6.4
Unimproved Channel Velocity

Average Slope (%)	Velocity (ft/s)	Velocity (ft/min)
< 2	7	420
2 to 5	10	600
> 15	15	900

Section 7

General Guidance for Non-Structural BMPs

7.0 GENERAL GUIDANCE FOR NON-STRUCTURAL BMPS

Non-structural solutions for stormwater management include BMPs that retain or restore and conserve existing natural soil, vegetative, and hydrologic conditions to reduce stormwater runoff, filter contaminants, and improve water quality. These BMPs differ from structural BMPs in that they are not engineered specifically to collect, convey, and/or store stormwater runoff, but they can be used in conjunction with structural BMPs and are recommended for use with APWA Section 5600 or local regulations. This chapter describes non-structural BMPs and how to apply them to site design and development. Non-structural BMPs are used to conserve various types of undisturbed areas and establish native landscaping in selected environments. The non-structural BMPs described in this section also serve as the foundation for design and construction of structural BMPs as presented in Chapter 8 of this manual.

For stormwater management, one of the primary goals of site development should be minimizing site disturbance and maintaining native, natural site conditions. Impervious or paved areas should be minimized. Land that is undisturbed or restored to its natural condition will allow more water to infiltrate, reducing the amount of runoff, erosion, and potential for downstream pollution. Vegetation left in place, particularly native vegetation, slows surface runoff, filters out sediment and sediment-bound pollutants; and encourages infiltration.

As developed areas expand, regions previously undisturbed experience increased stress from invasive species, altered soil and hydrology, and other changes to the ecosystem. With increased imperviousness, peak stormwater runoff quantities also increase, moving water more rapidly away from the site. An area may actually become more a droughty or xeric environment as less water from the soil profile is available to plants. Streams experience periodic higher, more destructive flows, destabilizing their banks and eroding surrounding properties. Exotic vegetation placed on the landscape requires more chemicals and water to sustain it, requiring more expense and energy to maintain a green façade. When such development occurs, increased attention to vegetation management and on-site soil protection is essential to maintain or improve water quality. To accomplish this, a site landscaping plan should include the native flora and fauna of the local region (impacted or not) as an integral component of the site planning process.

Planting design for BMPs, both non-structural and structural, is not simply a selection of plant species likely to survive, but it is a purposeful process that identifies native plant species and understanding their complex community associations. “Native species” include vegetation indigenous to the area, that is, plant species that existed in the region (typically within a 100- to 150-mile radius) before settlement. Their traits uniquely adapt them to local conditions. Ideally, a site developer establishing or restoring native plant communities understands the relationship between plant species and their natural environment, including related plant species associations, hydrological regime, soil conditions, and available light. To achieve this goal, using an experienced landscape architect or plant ecologist to develop a successful plan is strongly advised.

Minimizing site disturbance and conserving native vegetation also benefits the developer by reducing problems associated with erosion during construction. With increased regulatory requirements for erosion and sediment control, establishing a sound vegetation conservation plan will provide key strategies for stabilizing sites during construction while also reducing costs required for expensive erosion control strategies. One successful way to minimize native vegetation disturbance is to use construction site phasing—disturbing only a portion of the site at any time. If phased site construction is not feasible, construction sites should not be left bare for a period longer than 14 days, during which the site is temporarily seeded to a cover crop. Both approaches are detailed in Chapter 10.

The following subsections describe practices that can be implemented for non-structural BMPs that will contribute significant stormwater management functions, including:

- Soil Management - Preservation
- Soil Management - Restoration
- Restoration of Native Vegetation

- Uplands
- Bottomlands and Floodplains
- Stream Buffers

7.1 SOIL MANAGEMENT - PRESERVATION

7.1.1 Description

Photo courtesy of AES

For all development sites, soil management must be a key consideration for successful construction, including structures, successful erosion and sediment control, to final landscape design and implementation. Midwest soils tend to be high in clay, and the common misperception is that clay soils will not allow effective infiltration of water. Regional soils in their native condition are often rich in organic matter and root channels, providing rapid infiltration of water, retain a substantial water-holding capacity, and provide water for plants during longer periods of time. It is important, therefore, to conserve native soil conditions to the extent possible during development to maximize the benefits of the naturally developed soil profile.

7.1.2 General Application

While it is inevitable that soil will be disturbed during most construction activities, preservation of native soil conditions should be a component of all construction planning and processes. To retain or restore soil to a near-native condition, pre-construction soils should be evaluated and mapped. A well-conducted soil survey of a development site will include, at a minimum, a review of the county soil survey to gain knowledge of the site soil conditions, including the profile horizons, soil texture, drainage, and engineering qualities of the site. However, on-site evaluation of soil conditions is preferred, as this information will provide the developer with knowledge of specific conditions of the site, including drainage, soil depth, soil texture, and changes in soils across the site. Understanding these characteristics can provide insight for the developer's design team to optimally place structures, place roads, drainage features, and greenspace, and plan for phasing the project.

7.1.3 Advantages

The advantage of preserving native or natural soil conditions during and after site construction activities include:

- Reduced need for grading the site to conform to a non-natural topography, reducing site development costs.
- Reduced need for erosion control measures if existing vegetation is left in place.
- Less stormwater runoff with reduced need for detention pond construction and maintenance.
- Improved conditions for post-construction landscaping applications.
- Less need for importing topsoil for landscaping applications.
- Improved long-term stormwater management factors:
  - ◊ Increased infiltration (permeability) for stormwater
  - ◊ Better rooting environment for vegetation
  - ◊ Less long-term maintenance required

7.1.4 Disadvantages

Disadvantages of native/natural soil preservation include:

- Change from current accepted methods of site development
- May require variances from existing development codes
- May require "double handling" of the soil in areas where excavation or other disturbances occur
- May increase variability in site soil conditions

7.1.5 Design Criteria

Most counties publish soil surveys prepared by the NRCS, formerly Soil Conservation Service (SCS). These surveys provide information about general soil associations and series found within each county — soil associations and series delineations on aerial photos; descriptions of soil profiles; suitability for various land uses; wildlife habitats; crops and vegetation production yields; and various engineering and chemical properties. Site development activities within areas previously disturbed by urban developments (such as site grading, road construction, and other soil disturbance activities) may require additional soil investigations to determine limits of the remaining, undisturbed, native soils types and boundaries. Where natural soil conditions will be restored, additional investigations of native soil may be needed. Qualified individuals such as professional soil scientists, practicing NRCS soil scientists, or other geoscience professionals trained in mapping soils should prepare soil surveys according to the latest soil survey methods approved by the NRCS. Generally, soils are identified through field investigations and mapping to the first or second order survey.

If it is necessary to disturb soils, the following steps provide basic guidance for re-establishing good soil quality. More detail is provided in Appendix A:

- Remove soil from the disturbed site carefully by horizons (e.g. 'A' horizon, 'B' horizon, etc.) and stockpile the soils from each horizon separately. If they are to be stockpiled for an extended period of time, they should be covered to minimize erosion of the soil.
- After construction, replace soil starting with soil from the lowest horizon first, grading the soil to the original contours as much as possible. The soils should be minimally compacted. The 'A' horizon soil, or the topsoil, should be replaced last. The 'A' horizon should be as near to its original depth as possible.
- Avoid excessive compaction of the soils. No fertilization is necessary if the topsoil has been replaced. The soil surface should be granular, not compacted or crusted. If the soil surface is crusted (for example, after a rain), the surface should be broken when seeding for new vegetation.
- When replacing the soil, settling must be accounted for. If the soil is roughly replaced, with little care, the soil will redistribute itself, sometimes creating undesirable contours in the landscape. If this happens, re-grading of the soil may be necessary.

7.1.6 Native Soil Restoration and Protection

Standards for native soil restoration and protection are published in two primary sources:

NRCS. 1994. NRCS Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater.

Office of Surface Mining. 1983. 30 CFR Sec. 816.22. "Topsoil and Subsoil Performance Standards". May 16.

These standards promote the following primary soil restoration and protection goals: (1) to salvage, stockpile, and restore natural soil profile(s) properly, and (2) to protect restored soils from compaction and erosion where permanent native or naturalized vegetation is to be planted and maintained. Permanent native or naturalized vegetation established on restored native soil can also benefit other BMPs such as stream buffers, engineered swales, and open space areas.

7.1.7 Maintenance

Inspect restored areas periodically to monitor plant survival and erosion problems. Protect these areas from excessive vehicular and pedestrian traffic, as well as other potential damage caused by weather events, wildlife, and humans. Replace dead trees, shrubs, and herbaceous vegetation. Periodically interplant appropriate native species; control undesirable vegetative species; and remove excessive storm debris.

7.2 SOIL MANAGEMENT - RESTORATION

Photo courtesy of AES

7.2.1 Description

Not all development sites have natural or native soil conditions, a result of previous disturbance such as farming, land forming/grading, or other urban uses. When these conditions exist, soil restoration should be considered as a component of successful site construction and stormwater management. Typically, these soils will be missing much or all of the 'A' horizon or topsoil, and often much of the upper 'B' horizon, leaving soil that has less organic matter, poorer drainage, and may not be optimal for landscaping purposes. Often, these sites have previously been graded, exposing poor, clayey subsoils with poor drainage and high stormwater runoff. It is important, therefore, to restore soil conditions to the extent possible during development to capture the benefits of a natural soil profile.

7.2.2 General Application

At sites where soils have been drastically disturbed or modified, restoration of soil quality should be a component of all construction planning and processes. It is expected that soil restoration will likely be a post construction activity. To restore optimal soil quality, the pre-construction soils should be evaluated and mapped, and a plan established that identifies locations and resources necessary for restoring soil conditions. A well-conducted soil survey of a development site will include, at the least, a review of the county soil survey to gain knowledge of the site soil conditions before the site was disturbed, or a survey of nearby soils that will include the profile horizons, soil texture, drainage, as well as engineering qualities of the site. An on-site evaluation of soil conditions is preferred, as this information will provide the developer with knowledge of specific conditions of the site, including drainage, soil depth, soil texture, and changes in soils across the site. Understanding these characteristics can provide insight for the developer's design team to optimally place structures, roads, drainage features, and greenspace.

7.2.3 Advantages

The advantage of restoring optimal soil conditions include:

- Improved conditions for post-construction landscaping applications and establishing vegetation.
- Reduced long-term vegetation management
- Improved long-term stormwater management factors:

◊ Increased permeability for stormwater infiltration and less runoff volume

◊ Better rooting environment for vegetation

◊ Less long-term maintenance required

7.2.4 Disadvantages

Disadvantages of soil restoration include:

- Development and implementation of soil restoration strategy: topsoil, organic matter, conditioners.
- May require "double handling" of the soil in areas where excavation or other disturbances occur
- May increase variability in site soil conditions

7.2.5 Design Criteria

To restore soil quality to good or even optimal condition, the pre-construction soils should be evaluated and mapped. A well-conducted soil survey of a development site will include an on-site evaluation of soil conditions, including drainage, soil depth, soil texture, and changes in soils across the site. Understanding these characteristics can provide insight for the developer's design team to optimally place structures, place roads, drainage features, and greenspace, and plan for phasing the project.

Soil surveys prepared by the NRCS will provide information about general soil associations and series found within each county that can provide information about nearby soils and conditions that restoration can be targeted to. Where natural soil conditions will be restored, additional investigations of native soil may be needed. Qualified individuals such as professional soil scientists, practicing NRCS soil scientists, or other geoscience professionals trained in mapping soils should prepare soil surveys according to the latest soil survey methods approved by the NRCS. Generally, soils are identified through field investigations and mapping to the first or second order survey.

Even on disturbed soils, the following steps provide basic guidance for re-establishing good soil quality.

- Remove good quality soil from the disturbed site carefully by horizons (e.g. 'A' horizon, 'B' horizon, etc.) and stockpile the soils from each horizon separately. If they are to be stockpiled for an extended period of time, they should be covered to minimize erosion of the soil.
- After construction, replace soil starting with soil from the lowest horizon first, grading the soil to the original contours as much as possible. The soils should be minimally compacted. The 'A' horizon soil, or the topsoil, should be replaced last. The 'A' horizon should be as near to its original depth as possible.
- During final grading of soils, avoid excessive compaction of the soils. Use farm or soil preparation implements to break compacted or hardened soils. Where necessary, mix soil conditioners (organic matter such as compost, or chemical additions) into the soil. If possible, place and grade good quality topsoil (at least four inches) as the surface soil before planting vegetation. No fertilization is necessary if the topsoil has been replaced. The soil surface should be granular, not compacted or crusted. If the soil surface is crusted (for example, after a rain), the surface should be broken when seeding of new vegetation occurs.
- When replacing the soil, settling must be accounted for. If the soil is roughly replaced, with little care, the soil will redistribute itself, sometimes creating undesirable contours in the landscape. If this happens, re-grading of the soil may be necessary.

7.2.6 Native Soil Restoration and Protection

Standards for native soil restoration and protection are published in two primary sources:

NRCS. 1994. NRCS Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater.

Office of Surface Mining. 1983. 30 CFR Sec. 816.22. "Topsoil and Subsoil Performance Standards". May 16.

These standards promote the following primary soil restoration and protection goals: (1) to salvage, stockpile, and restore natural soil profile(s) properly, and (2) to protect restored soils from compaction and erosion where permanent native or naturalized vegetation is to be planted and maintained. Permanent native or naturalized vegetation established on restored native soil can also benefit other BMPs such as stream buffers, engineered swales, and open space areas.

7.2.7 Maintenance

Inspect restored areas periodically to monitor plant survival and erosion problems. Protect these areas from excessive vehicular and pedestrian traffic, as well as other potential damage caused by weather events, wildlife, and humans. Replace dead trees, shrubs, and herbaceous vegetation. Periodically interplant appropriate native species; control undesirable vegetative species; and remove excessive storm debris.

7.3 RESTORATION OF NATIVE VEGETATION

Photo courtesy of AES

Vegetation management is critical to the success of stormwater BMPs, particularly native vegetation. All native vegetation, when it is newly-planted, requires care and maintenance. Native landscapes – those that are planted to native vegetation – provide the advantages of plants that are adapted to the area or region within which the BMPs are to be used. Native landscapes by themselves are effective stormwater BMPs that don't require engineering design and require less maintenance over time. This section provides general guidance for establishment of native vegetation for site restoration, including designed landscape features, as well as establishing native vegetation for both non-structural and structural BMPs. Section 8.0 provides general guidance for structural BMPs such as bioretention basins, vegetated swales, rain gardens, and other BMPs. Underlying the success of any of these BMPs is the successful establishment and maintenance of native vegetation.

7.3.1 General Application

Native vegetation reduces stormwater runoff by intercepting rainfall in its canopy, reducing surfacewater velocity across the ground surface, and by increasing the infiltration capacity of the soil by extending deep roots and facility soil microbial interactions that create permeable soil structure – even in clays. Native vegetation should be conserved where possible in urban as well as suburban and rural areas to facilitate improved stormwater management. It is a primary component of the natural landscape as well as for structural BMPs.

7.3.2 Advantages

Native vegetation provides the following advantages:

- Because it is indigenous to the area, it will be able to thrive in the local climate with less maintenance.
- Deep roots enhance stormwater infiltration into the soil.
- With deep-rooted nature, native vegetation is able to withstand flooding events as well as extended dry periods.
- Reduces flow velocity of stormwater runoff.

- Can be used in total landscape design in restoration of native prairie, woodland, wetlands, and riparian areas, or as landscape features.
- Attracts wildlife and improves biological diversity.
- Requires little to no fertilizer or chemical maintenance, as well as reduced amounts of water to survive.
- Provides attractive and natural vegetative scenery.

7.3.3 Disadvantages

- Native vegetation can be difficult to establish if some circumstances.
- Native vegetation can be expenses if planted from nursery stock plugs.
- Considered "weedy" by some people.

7.3.4 Design Considerations

For use of native vegetation for stormwater BMPs, both non-structural and structural, consider the location of BMP (for example, parking lot, street scape, or yard) and the types of vegetation most appropriate for that location. Consider effective height of vegetation and general appearance of landscaping features. Select vegetation considering slope, aspect, drought, and water tolerance; and (if relevant) salt tolerance. When appropriate, mix small trees, shrubs, grasses, sedges, and forbs to achieve maximum diversity.

If native restoration and landscaping is to be achieved (prairie, woodland, wetland, or riparian areas), consult a restoration ecologist about the native environment that existed in the area and the localized conditions that will support the native vegetation restoration. Soils and hydrology should be considered and evaluated, and the extent of the restoration (small area vs. several acres) to determine the vegetation composition and diversity.

Restoration planning of native vegetation for non-structural and structural BMPs includes mechanical and chemical removal of exotic invasive species, reduction of other undesirable trees and brush, re-introduction of fire, removal of dams or breaking of tiles, removal of debris within the restoration site, treatment of erosion and contamination problems, and manual or mechanical installation of native seeds and plants, including larger shrubs and trees.

7.3.5 Planting Densities

Complement natural features within and adjacent to the site with suitable location, layout, and appearance of the BMP to be constructed. As a general rule of thumb, use the following densities for trees and shrubs:

TABLE 7.1
Planting Densities for Stormwater BMPs

Plant Types/Heights	Plant Spacing
Small Shrubs (<10 feet)	3 to 6 feet
Large Shrubs / Small Trees (10 to 25 feet)	6 to 8 feet
Large Trees	8 to 16 feet
Wetland and Aquatic Species (1 to 3 feet)	1 to 2 feet

Consider depths of detention and permanent water pools when selecting vegetation for wetland or frequently inundated areas. Avoid shrubs that block the view of other vital aspects. Do not introduce tree species with low hanging branches if a trail is nearby.

Recommendations for plant materials for most non-structural and structural BMPs is provided in Appendix A, Section 2.

7.3.6 Maintenance

Native vegetation used in stormwater BMPs does require maintenance, but not as frequently as traditional, exotic landscaping. Natural community responses to restoration treatments, however, can be dynamic and unpredictable. For this reason, native landscape management and maintenance strategies need to be flexible and allowed to change over time to respond to natural communities as they adjust to restoration intervention treatments. Careful monitoring and evaluation of community responses are critical steps in an adaptive management process. This allows for measured changes in the timing and application of specific treatments to better improve the overall performance of the site.

For these reasons, a vegetation management plan should be developed that allows adaptive management, not absolute prescriptive management. The plan is a starting point in an ongoing process that relies on monitoring to provide feedback on program effectiveness and for evaluation of the need and justification for changes in the management plan. This process of evaluation, adjustment, refinement and change is adaptive management, and it is fundamental to the effective restoration and management of natural communities. Adaptable management and maintenance plans are fundamental to the health, longevity, and ultimate success of the restored native landscapes.

Maintenance tasks may include periodic use of chemical and mechanical removal of invasive species, and modest enhancement seeding and planting. While this phase of the program can be viewed as a routine maintenance program conducted annually at strategic times to achieve and maintain specific ecological and biological objectives, management decisions must remain responsive to the guiding principle of adaptive management.

General, on-going tasks include inspection of both non-structural and structural BMPs periodically to monitor plant survival. BMPs need to be protected from excessive pedestrian traffic; pest infestations; and other potential damage caused by storm events, wildlife and humans.

Specialized training for restoration and management tasks of any vegetation is often necessary. For many of the restoration tasks (i.e. prescribed burning, herbicide use, and monitoring) specialized training, often licensing or certification, and oversight and guidance are required well in advance of the dates for commencement of the restoration program. Personnel and volunteers involved in prescribed burning, brush control, monitoring, seed collection, etc., should receive training commensurate with the activity in which they would be involved. Training is especially important for those activities that may have risk and safety implications (i.e. prescribed burning), but also for monitoring, where an accurate assessment of the ecological performance of the ecological system to the restoration treatments is required.

7.4 UPLANDS

"Uplands" are those areas that are typically elevated above bottomlands and floodplains, retaining well-drained hydrologic conditions. Prairie grasses and a few tree species typically dominate undisturbed and native landscaped uplands. Numerous prairie grasses are native to the eastern Kansas and western Missouri region, including (but not limited to), big bluestem, little bluestem, indian grass, switchgrass, prairie dropseed, western wheatgrass, and Canada wild rye. Upland tree species include, but are not limited to, hickory, oak, hackberry, and black locust, among others.

Photo courtesy of AES

7.4.1 General Applications

Upland areas provide the first and primary point of stormwater management. It is in these uplands that rainfall will infiltrate into the soil and provide subsurface drainage, recharging groundwater conditions and maintaining perennial stream flow. Native vegetation intercepts and catches rainfall, reducing the amount that hits the ground, allowing evaporation of a significant portion of precipitation. The rainfall that reaches the ground infiltrates into the soil where it is held for plant use, or may slowly seep to stream systems. This process reduces the amount and velocity of water moving into lower areas, minimizing flooding conditions and protecting properties. Upland vegetation filters sediment and other pollutants from stormwater runoff while also providing wildlife habitat and aesthetic values for the public.

7.4.2 Advantages

- Preserves predevelopment hydrology effectively—especially streams, ponds and lakes
- Slows surface flows, promotes infiltration, and reduces erosion
- Traps sediment and sediment-bound pollutants
- Improves soil structure
- Typically requires less maintenance than non-native landscaping
- Preserves wildlife habitat and provides aesthetic and recreational benefits
- Requires significantly less maintenance expense

7.4.3 Disadvantages

- Reduces the area of land available for development
- Limits construction to locations around open space
- May require a cover crop
- Cannot be established during winter.

7.4.4 Design Criteria

To establish native uplands, choose plant species suited to the location. Consider moisture regimes, soils, light levels, runoff properties (pollutants, concentrated flow, and sheet flow), intended land use, and level of maintenance. Determine seeding rates considering the intended purpose of the site. Decide how to apply the seed (for example, broadcasting, drilling, or hydroseeding). Determine correct fertilization rates, if required, by soil testing. Submit soil samples to a qualified laboratory or to the local county extension service for nutrient testing. Seedbed preparation is critical to success of plantings—so do not over compact the soil.

7.4.5 Maintenance

Conserving existing upland native vegetation demands less maintenance than turf grass plantings or other landscaping, reducing operations and maintenance costs. Minimal mowing and herbicide application is needed to maintain a healthy stand of native vegetation. Some mechanical means may be necessary to control invasive species and preserve the health of the system. Minimal to no fertilization is required. Establishing native uplands necessitates that seeded areas be kept moist during the first weeks of establishment; mulch is also recommended. Reseeding may be necessary when the first seeding does not produce a vigorous stand.

Mowing is only occasionally necessary, and fertilizers are not required to maintain a healthy stand of native vegetation. If controlled burning is not an option, mowing can control unwanted deciduous growth that may encroach on prairie plantings.

7.5 BOTTOMLANDS AND FLOODPLAINS

Photo courtesy of AES

Bottomlands are defined as low-lying lands along a watercourse that floods frequently. The floodplain is a level surface of stratified alluvial soils on either side of a watercourse; it is typically built up by silt and sand, carried out of the main channel, and submerged during times of flood. Undisturbed bottomlands and floodplains typically host a diverse assemblage of plant species.

Preserving bottomland and floodplain vegetation during development maintains a natural buffer that can filter out sediment from runoff before it enters the watercourse; and reduce the velocity of surface water runoff, thus decreasing the potential for erosion.

Typically, soils near a watercourse in the floodplain have high water tables and lo- bearing strength. Along with the prospect of frequent flooding, this limits construction feasibility and encourages preservation of bottomlands and floodplains. The habitat of bottomlands and floodplains often provides a desirable environment for aquatic and terrestrial wildlife, giving the public an opportunity for recreations such as fishing or observing wildlife.

7.5.1 Advantages

- Most effectively preserve predevelopment hydrology
- Slow surface flows, which promotes infiltration and reduces erosion
- Trap sediment and sediment-bound pollutants
- Improve soil structure
- Host microorganisms and plants that transform nutrients into usable forms and can break down pollutants
- Preserve wildlife habitat and provide aesthetic and recreational benefits.

7.5.2 Disadvantages

- Reduce amount of developable land
- Limit construction to locations around open space.

7.5.3 Design Criteria

To establish floodplain and bottomland vegetation:

- Choose plant species suited to the location.
- Consider moisture regimes, soils, light levels, runoff properties (pollutants, concentrated flow, and sheet flow), intended land use, and level of maintenance.
- Determine seeding rates considering the intended purpose of the site. Decide how to apply the seed (for example, broadcasting, drilling, or hydroseeding). .
- Submit soil samples to a qualified laboratory or to the local county extension service for nutrient testing. Seedbed preparation is critical to success of plantings—so do not over compact the soil.

7.5.4 Maintenance

Once established, native vegetation in floodplains requires little maintenance. Depending on the desired use of the floodplain, general maintenance may require replacement of dead or undesirable trees and shrubs to prevent overpopulation of undesirable species; selectively harvesting trees and shrubs to reduce overgrowth, and control of invasive species. Mechanical means or prescribed burning may be necessary to manage the area.

For wetlands, ponds or frequently inundated areas, inspect the areas periodically to monitor plant survival. Protect it from excessive sedimentation; pest infestations; and other potential damage caused by storm events, wildlife, and humans. Replace dead trees, shrubs, and herbaceous vegetation. Periodically control undesirable vegetative competition. Remove excessive buildup of sediment, storm debris, and trash.

7.6 STREAM BUFFERS


Photo courtesy of AES

Stream buffers are important BMPs to be included when determining the proper package of BMPs (as directed in Section 4). They are defined as strips of heavy herbaceous and woody vegetation along streams (perennial and intermittent) and open bodies of water. They help reduce the impact of runoff by trapping sediment and sediment-bound pollutants, encouraging infiltration, and slowing and dispersing stormwater flows over a wide area. They help preserve streambank stability by reinforcing the soil with root systems. In addition, they provide detritus and biomass for aquatic and terrestrial habitat, shade cover to manage stream temperatures, and wildlife corridors (USDA 1999).

APWA Section 5605.3 specifies stream buffers for all drainage areas greater than 40 acres, and recommends that cities adopt comprehensive stream preservation and buffer zone requirements as part of their master plan. Stream buffer creation and maintenance also may be required and enforced by development codes and city ordinance.

7.6.1 Advantages

- Most effectively preserve predevelopment hydrology—especially streams, ponds, and lakes
- Slow surface flows, which promotes infiltration and reduces erosion
- Trap sediment and sediment-bound pollutants
- Improve soil structure
- Transform nutrients into usable forms and break down pollutants via actions of microorganisms and plants
- Preserve wildlife habitat and provide aesthetic and recreational benefits
- May lower water temperature
- Provide floodplain protection from erosion.

7.6.2 Disadvantages

- Reduce amount of developable land
- Limit construction to locations around open spaces
- May require a cover crop in zone 3

7.6.3 Design Criteria

APWA Section 5605.3 does not specify multiple zones. From a design perspective, stream buffers consist of minimally two zones; however, they are more effective if they have three zones. Zone 1 typically extends from the water's edge or top of bank for a set distance to protect the immediate streamside area, and is planted with fast growing tree and shrub species suited for the site. Riparian grasses and wildflowers are also recommended to help stabilize soils and add diversity to the area. Activities and structures are most restricted in this zone. Zone 2 extends from the edge of Zone 1 and includes slower growing tree species and shrubs as well as native grasses and forbs. The width of Zone 2 may be set or variable. No permanent structures are permitted in this zone, but more intensive activities may be permitted, such as hiking and biking trails. Where appropriate, Zone 3 is upgradient of Zone 2 and provides a buffer to protect Zones 1 and 2. This zone may include more intensive activities such as residential landscaping, but no permanent structures. Design criteria from NRCS and Johnson County, Kansas are provided below. Table 7.2 shows recommended vegetation for stream buffers.

According to Section 5605.3, buffer widths as measured from the ordinary high water mark (OHM) outward in each direction shall exceed the following:

TABLE 7.2
Stream Buffer Widths

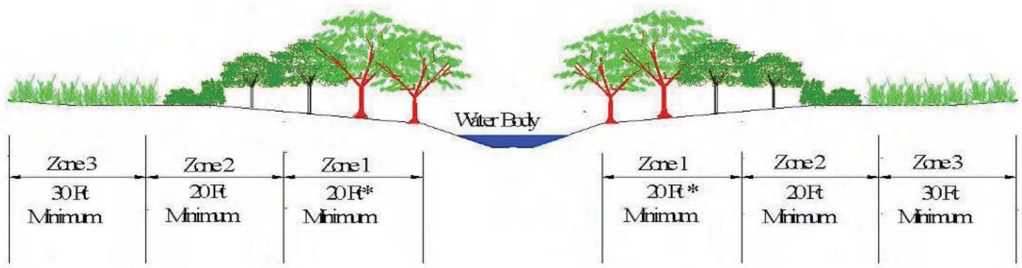
Contributing Drainage Area	Buffer Width, from OHM Outwards
Less than 40 acres	40 feet
40 to 160 acres	60 feet
160 to 5,000 acres	100 feet
Greater than 5,000 acres	120 feet

Design criteria should be adapted to incorporate these minimum widths. According to NRCS design standards for Kansas, Zone 1 shall begin at the waterline or top of bank and extend for a minimum of 15 feet. Where an active floodplain is connected to the water body, the combined widths of Zones 1 and 2 should be the smaller of 30 percent of the floodplain or 100 feet. Runoff entering Zone 3 of the buffer must be sheet flow. A flow spreader may be required to ensure that concentrated flows do not occur. The width of Zone 3 must be 33 percent of the contributing area length with a minimum of 30 feet and maximum of 120 feet. Zone 3 vegetation should include permanent, native herbaceous vegetation consisting of grasses, sedges, and forbs. The NRCS specifies a minimum buffer width of 35 feet; however, the minimum width should be increased in keeping with Section 5600. When establishing a stream buffer, select appropriate methods of planting and seeding (USDA, 1999; see Appendix A). Figure 7.1 provides a representative stream buffer zone schematic.

7.6.4 Maintenance

Once established, native vegetation in stream buffers requires little maintenance. General maintenance may require replacement of dead or undesirable trees and shrubs to prevent overpopulation of undesirable species; selectively harvesting trees and shrubs to reduce overgrowth, and control of invasive species. Mechanical means or prescribed burning may be necessary to manage the area.

For frequently inundated areas, inspect the stream buffer periodically to monitor plant survival. Protect it from excessive sedimentation, pest infestations, and other potential damage caused by storm events, wildlife, and humans. Replace dead trees, shrubs, and herbaceous vegetation. Periodically control undesirable vegetative competition. Remove excessive buildup of sediment, storm debris, and trash.



Source: USDA 1999;
* modified in accordance with APWA Section 5605.3

Figure 7.1 - Stream Buffer Zone Placement Example

Section 8

General Guidance for Structural BMPs: Engineered Systems

8.0 GENERAL GUIDANCE FOR STRUCTURAL BMPS: ENGINEERED SYSTEMS

If minimizing site disturbance and introducing native landscaping practices are not feasible during site development, select engineering practices to promote infiltration, water storage and water treatment. Structural BMPs differ from nonstructural practices in that they are engineered to manage stormwater for water quality treatment. Many structural BMPs ally native vegetation with man-made materials and engineered subgrades to help control runoff

As described in section 5, structural BMPs may promote some combination of infiltration, filtration, detention, and water quality treatment. BMPs that promote infiltration include, but are not limited to; bioretention, pervious pavement, rain gardens, and sand filters. Structural BMPs that provide on-site filtration include bioretention, swales, and sand filters. On-site stormwater detention is storage of excess runoff before its entry into principal drainage system. Extended wet and dry detention and extended detention wetlands are examples of detention practices. Incorporate them into the site design to preserve native landscaping when infiltration practices are not possible. Finally, manufactured devices such as inlet inserts, baffle boxes and hydrodynamic separators provide water quality treatment without providing any storage.

The design guidelines in this section provide detailed descriptions of each type of BMP as well as guidance for its use and a detailed design example of each.

8.1 RAIN GARDENS

Targeted Constituents

Sediment	●
Nutrients	◍
Trash	●
Metals	●
Bacteria	●
Oil and Grease	●
Organics	●

Legend (Removal Effectiveness)

High	Medium	Low
●	◍	○

8.1.1 Description

A rain garden is an infiltration device consisting of a small excavated area that is covered with a mulch layer and planted with a diversity of woody and herbaceous vegetation. Storm water directed to the device percolates through the mulch and into the native soil, where it is treated by a variety of physical, chemical and biological processes.1 Generally, a rain garden is a small depression planted with native wetland and prairie vegetation (rather than a turfgrass lawn) where stormwater runoff collects and infiltrates. Runoff can be from sheetflow or from direct discharge from rain spouts, swales, or directed drainage from impervious areas on a property. Rain gardens function similar to larger-scale bioretention areas, providing collection and infiltration of rainwater, reducing runoff into the common stormwater system. Rain gardens can provide effective contributions to stormwater runoff reduction if they are sufficient in number and common throughout an area. Individual gardens also aid in controlling the volume of runoff from individual lots that would otherwise combine with and contribute to runoff from other properties into the stormwater sewer system.

8.1.2 General Application

Rain gardens can be used to enhance stormwater runoff quality and reduce peak stormwater runoff rates from small sites. Rain gardens can be used to improve the quality of urban/suburban runoff coming from roof tops, driveways, and lawns of residential neighborhoods, small commercial areas, and parks. They are typically most effective for catchments less than one acre. They can be used as an onsite BMP that works well with other BMPs, such as upstream onsite source controls and downstream infiltration/filtration basins.

8.1.3 Advantages/Disadvantages

8.1.3.1 General

Rain gardens are promoted and designed as native landscapes that add to aesthetic appearances of properties while reducing peak runoff rates and improving water quality. In residential application, they are intended to provide the enjoyment of gardening and observing native plants and wildlife as well as serving an important drainage and stormwater function for the homeowner. They are effective in removing particulate matter and the associated heavy metals and other pollutants. As with other BMPs, safety issues need to be addressed through proper design.

8.1.3.2 Physical Site Suitability

Normally, the area required for rain garden may be from 10 to 40 percent of it's catchment area, depending on the amount of impervious area, soil conditions, and types of plants used. Site specific soil testing to check infiltration is appropriate to determine the design requirements of the rain garden. If infiltration rates are less than 0.10 inch per hour[2] (typical of a clay loam soil), the soil is not suitable for a rain garden, or the site may need an engineered soil mix to promote infiltration. Rain gardens using an engineered soil mix should use a 1:1 sand/compost mix to a depth of approximately two feet if the soil is deep enough. Rain gardens should be placed near the end of a runoff area before stormwater leaves the site, or in a low area of the property where water collects. Factors limiting the effectiveness of rain gardens include slope, depth and type of soil, and available area for the rain garden.

8.1.3.3 Pollutant Removal

Raingardens are effective in removing from 30 to 90 percent of nutrients (such as nitrogen and phosphorus) and 80 percent of sediments as well as reducing runoff volumesRemoval of suspended nutrients, solids, and metals can be moderate to high.

A major factor controlling the degree of pollutant removal is the volume and rate of stormwater runoff captured by the rain garden that filters through the vegetation and infiltrates into the soil. The rate and degree of removal may depend on the amount of time that the garden remains saturated, with varying degrees of nitrate and phosphorus removal depending on the buildup of organic materials in the raingarden, and plant uptake. Metals, oil and grease, and some nutrients have a close affinity for suspended sediment and will be removed partially through sedimentation.

8.1.3.4 Aesthetics and Multiple Uses

Rain gardens should be designed to drain within 24- to 48-hours. It's not unusual, however, for rain gardens to be inundated frequently. Vegetation planted in parts of the rain garden that are frequently inundated should be species that can survive both frequently wet or often dry conditions. In this respect, native wetland or mesic wetland species can be planted that facilitate both excellent drainage as well as aesthetic qualities.

Because rain gardens are intended to be aesthetically pleasing components of residential or small commercial properties, proper selection and placement of native species that are attractive and acceptable to land owners is important. Native species that are deep-rooted perennials are used to achieve the desired function of stormwater runoff capture and infiltration. Species selection for the rain garden should consider the drier portions of the garden (elevated berms to catch runoff) as well as the lower, wetter areas of the garden.

8.1.4 Design Considerations

Rain gardens can be designed to function individually or as part of a larger stormwater treatment system. Also, whenever possible, consider the recreational and aesthetic factors of gardening, and the wildlife function that can be served in a rain garden, even in urban areas. Main design components should include:

- The ponding depth of a rain garden is typically 4 to 6 inches. Some rain gardens, however, have deeper ponding depths that drain completely within two days.
- Limit ponding in the depressional area to 2 days or less to avoid nuisance insects.
- Clay soil will typically require amendments such as compost or peat to enhance porosity and more rapid root growth, and to improve infiltration during the first year. To provide better infiltration during the first year, a 1:1 sand/compost mix may be used in the raingarden.
- A layer of rich organic material and/or mulch should be placed over the soil in the depressional area. The organic material and/or mulch holds moisture and aids removal of metals.
- Rain gardens should be placed a minimum of 10 feet away from building foundations.
- Placement of the rain garden and overflow path should not interfere with adjoining property drainage patterns.
- Rain gardens should not be located in areas where ponded water may create problems for surrounding vegetation or land use.
- Construction and planting should be as early in the spring as possible to take advantage of spring rains. Watering as needed during dry periods during the first year may be necessary until the vegetation is established.

8.1.5 Design Procedure and Criteria

The following steps outline the design procedure and criteria for a rain garden.

- Determine an appropriate area for constructing the rain garden. Rain gardens should be placed near the lowest point of a catchment area, on slope not exceeding two percent. The location selected should have sufficient area available for the rain garden.
- Examine existing soil conditions and perform percolation tests if necessary. A simple percolation test involves excavating a hole approximately six inches deep and 12 inches in diameter and filling it with water. If the water does not drain within 24 hours, the soil may not be suitable for a rain garden, or will require soil amendments or and engineered soil mix to facilitate infiltration. Depending on location, size of the rain garden, and local requirements, a professional engineer may be required to conduct a percolation test of the selected site.
- Size the rain garden to intercept runoff from a water quality storm event. Sizing calculations must include runoff coefficients for the type of groundcover within the rain garden catchment area. The “footprint” area of the rain garden can vary depending on the amount of rain fall runoff intercepted, and the depth of the type of soil. Ponding depth of the rain garden should be restricted to six inches or less.
- If possible, the soil should be native topsoil or similar, with at least two- to five-percent organic material (brown to near black coloration). Tight, clayey soils (typical of subsoils left as the soil surface in many residential areas) should be amended with organic supplements to increase porosity. Sandier soils may not need amendments.

- Using native soils are preferred for the rain garden. If an engineered soil mix is used, a 1:1 sand/compost mix is recommended. The engineered soil mix must be thoroughly homogenized prior to placement in the rain garden. The underlying native soil should be scarified prior to placement of the engineered soil mix. Soil mixes can actually vary to also include a small portion of topsoil. The amount of engineered soil mix to use should be determined from the sizing calculations of the rain garden, but the depth of the soil mix should not exceed two feet.
- A small berm may be included in the design of the rain garden on the down-hill side. The berm should be at least 12 inches wide and constructed of the native topsoil.
- A filter strip of grass (native preferred but not necessary) is recommended for reducing velocity and for filtering fine sediments before water enters the rain garden. For rain gardens collecting runoff from parking lots or paved areas, a buffer strip of river rock, at least 12 inches wide, is recommended to reduce flow velocity.
- A planting soil composed of topsoil and compost on the surface of the rain garden is recommended. Above the planting soil, a two- to three-inch layer of mulch should be placed after vegetation is planted.
- Plant selection will include native species that are tolerant of both wet and dry cycles will achieve the highest level of success in a rain garden. Other non-native species can be added. Deep rooted perennials are encouraged. Trees and shrubs are also commonly used in rain gardens.

8.1.6 Maintenance & Inspections

Rain gardens should be weeded weekly until native plants are established. Surface mulch will aid in reducing the growth of unwanted vegetation. Fertilizer applications should be avoided, and minimized near the rain garden. After the rain garden is established, dead vegetation should be removed each spring by mowing or burning (if allowed). Allowing vegetation that goes dormant in the fall or winter to remain provides food for birds through the winter. After the rain garden is established, periodic maintenance to remove non-native invasive or un-desired plants, or to cut back excessive growth is appropriate. The following table provides general maintenance guidance[1]:

TABLE 8.1
Typical Maintenance Activities for Rain Gardens

Activity	Frequency
Water Plants	As necessary during first growing season
Water as necessary during dry periods	As needed after the first growing season
Re-mulch void areas	As needed
Treat diseased trees and shrubs	As needed
Inspect soil and repair eroded areas	Monthly
Remove litter and debris	Monthly
Add additional mulch	Once per year

8.1.7 Design Example

The procedure for sizing rain gardens is similar to the procedure for sizing bioretention cells without an underdrain system. See section 8.4.7 for example and omit the underdrain system design.

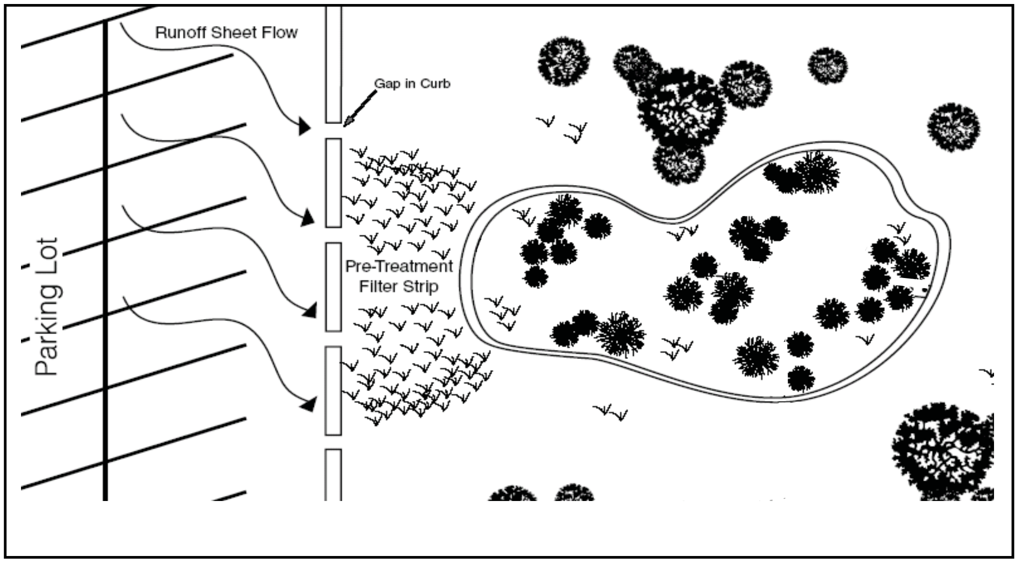
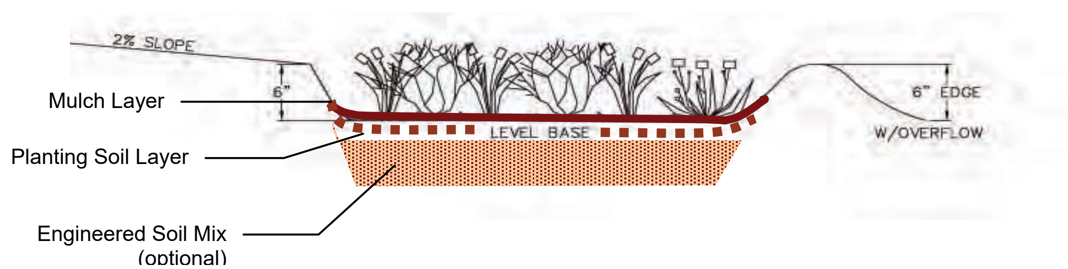


FIGURE 8.1 - Rain Garden Layout for Parking Lot Runoff



Typical Rain Garden Cross Section *(Source: Pennsyvania Stormwater BMP Manual, 2005)*

FIGURE 8.2 - Simplified Cross Section of Rain Garden Design

8.2 FILTRATION BASINS

Source: University of Wisconsin Extension-Water Resources Education

Targeted Constituents

Constituent	Removal
Sediment	◍
Nutrients	●
Trash	●
Metals	●
Bacteria	●
Oil and Grease	●
Organics	●

Legend (Removal Effectiveness)

High	Medium	Low
●	◍	○

Source: California Stormwater Quality Association, California Stormwater Quality Association Stormwater Best Management Practice Handbook. 2003.

8.2.1 Description

Infiltration basins are earthen structures that capture a stormwater runoff volume, hold this volume, and infiltrate it into the ground over a period of days. Typical components of an infiltration basin include an inlet, sediment forebay, level spreader, principal spillway, a backup underdrain, emergency spillway, and a stilling basin. Figure 8.3 illustrates a typical infiltration basin.

8.2.2 General Application

Infiltration basins are almost always placed off line and are designed only to intercept a certain volume of runoff. Any excess volume is bypassed. Vegetated infiltration systems help to prevent migration of pollutants; the roots of the vegetation can increase the permeability of the soils, thereby increasing the basin's efficiency. Infiltration basins typically are not designed to retain a permanent pool volume. Their main purposes are to transform a surface water flow into a groundwater flow and to remove pollutants through mechanisms such as filtration, adsorption, and biological conversion as the water percolates through the underlying soil. Design infiltration basins to drain within 72 hours to prevent mosquito breeding and potential odors from standing water, and to prepare the basin to receive runoff from the next storm (EPA, 1993a). Infiltration basins are also useful to help restore or maintain predevelopment hydrology in a watershed. Infiltration can increase the water table, increase baseflow, and reduce the frequency of bank-full flooding events. Infiltration basins are not well suited for drainage areas that deliver high concentrations of sediments. They are best used as a best management practice (BMP) toward the end of the treatment train. If groundwater is close to the surface, do not use an infiltration basin.

8.2.3 Advantages

- Reduce the volume of runoff from a drainage area
- Effectively remove fine sediment, trace metals, nutrients, bacteria, and oxygen-demanding substances (organics)
- Reduce downstream flooding and protect streambank integrity

- Reduce the size and cost of downstream stormwater control facilities and storm drain systems by infiltrating stormwater in upland areas
- Provide groundwater recharge and baseflow in nearby streams
- Reduce local flooding

8.2.4 Disadvantages

- Have potentially high failure rates due to improper siting, design, and lack of maintenance—especially if pretreatment is not incorporated into the design
- Carry a risk of groundwater contamination, depending on soil conditions and groundwater depth
- Have potential for clogging—not appropriate for treating significant loads of sediment and other pollutants
- Are not appropriate for industrial or commercial sites where release of large amounts or high concentrations of pollutants are possible
- Require flat continuous area
- Require frequent inspection and maintenance
- Have effectiveness limited to small sites (2 acres or less)

8.2.5 Design Requirements and Considerations

Restrict the contributing drainage area to any infiltration basin to 2 acres or less. Locate basins at least 150 feet away from drinking water wells to limit the possibility of groundwater contamination, and at least 10 feet downgradient and 100 feet upgradient from building foundations to avoid potential seepage problems. The length-to-width ratio for an infiltration basin should be 3:1 or greater. Grade the basin as flat as possible to provide uniform ponding and infiltration of the runoff across the floor. Be sure the side slopes of the basin are no steeper than 3 horizontal to 1 vertical (flatter slopes are preferred) to allow for proper vegetative stabilization, easier mowing, easier access, and better public safety. Select vegetation for the infiltration basin by its ability to withstand wet weather, drought, and short periods of ponding (Table 4.4 and Appendix A). Design the infiltration basin to store temporarily and infiltrate the WQv. The maximum depth of 2 feet and ponding time of the infiltration area should promote the survival of vegetation. Determine the ponding time by plant inundation tolerances—it must be no greater than 72 hours. Conservative estimates of soil infiltration rates are in county soil surveys published by the U. S. Department of Agriculture or are obtainable by field testing methods. After determining the infiltration rate of the soil, calculate the maximum depth of the infiltration basin using the following equation:

$$d_{\max} = (f)(T_p)$$

Where

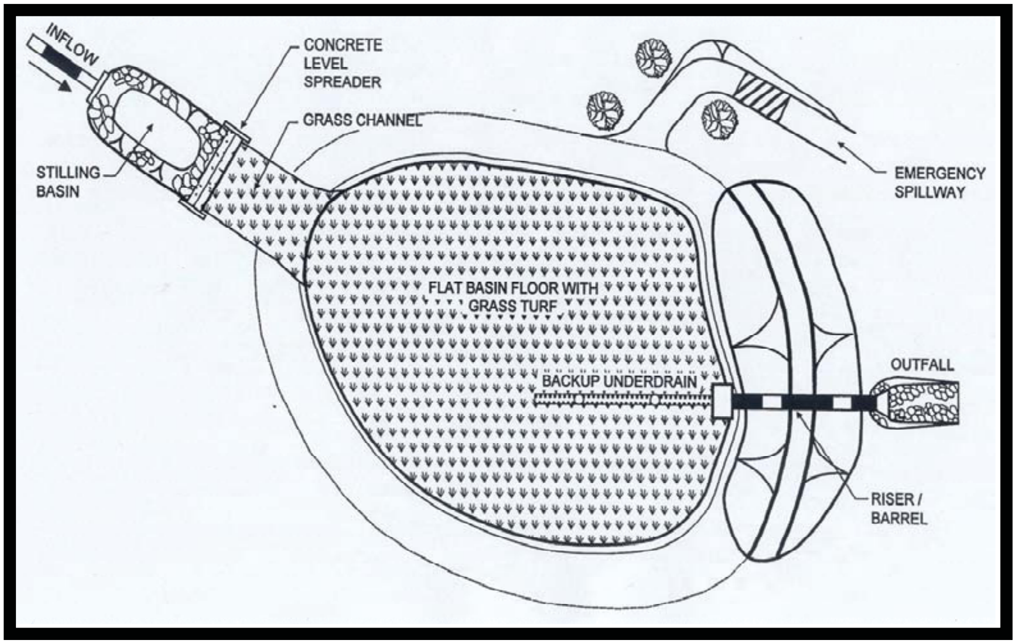
d_{max} = maximum design depth (inches)

f = soil infiltration rate (inches/hour)

$T_{p\,=}$ = design ponding time (hours)

Since infiltration basins are susceptible to high failure rates due to clogging from sediments, pretreating stormwater is necessary to remove as many suspended solids from the runoff as possible before the runoff enters the basin. The design of infiltration basins should include an appropriate combination of grit chambers (for pretreating), swales with check dams, filter strips, or sediment forebays and traps. Figure 8.3 shows an infiltration basin with pretreatment via a stilling basin.

If runoff is delivered by a storm drainpipe or along the main conveyance system, design the infiltration practice as an offline practice. To prevent incoming flow velocities from reaching erosive levels, stabilize inlet channels to the basin with riprap or other suitable methods, and design inlet channels to terminate in a broad apron (spreads the runoff more evenly over the basin surface to promote better infiltration). Incorporate a bypass flow path or pipe in the design to convey high flows—from storms larger than the water quality storm—around the basin. All basins must have an emergency spillway capable of passing runoff from the 25-year, 24-hour storm without damage to the impounding structure.



Source: CWP 1996

FIGURE 8.3 - Typical Infiltration Basin
(for informational purposes only)

8.2.6 Maintenance and Inpections

The following is a partial list of actions for proper upkeep of infiltration basins:

- Inspect and clean pretreatment devices associated with basins at least twice a year, and ideally every other month.
- Following every major storm for the first few months after the basin has gone on line, perform inspections to maintain proper stabilization and function. Pay attention to how long water remains standing in the basin after a storm; standing water within the basin more than 72 hours after a storm indicates the infiltration capacity may have been overestimated. Repair factors responsible for clogging (such as upland sediment erosion and excessive compaction of soils) immediately. Inspect newly established vegetation several times to determine if any remedial actions (e.g., reseeding, irrigation) are necessary.
- Thereafter, inspect the infiltration basin at least twice per year for differential accumulation of sediment, erosion of the basin floor, condition of riprap, and the health of the vegetation.
- Replant eroded or barren spots immediately after inspection to prevent additional erosion and accumulation of sediment.
- Remove sediment within the basin when the sediment is dry enough to crack and readily separates from the basin floor.
- To remove the top layer of sediment, use light equipment that will not compact the underlying soil.

- Control weed growth to maintain vegetation.

8.2.7 Design Example

See Addendum #1, to be completed at a later date.

8.3 INFILTRATION TRENCHES

Source: MDE Water Management Administration

Targeted Constituents

Constituent	Removal Effectiveness
Sediment	Medium
Nutrients	High
Trash	High
Metals	High
Bacteria	High
Oil and Grease	High
Organics	High

Legend (Removal Effectiveness)

High ● Medium ◐ Low ○

Source: California Stormwater Quality Association, California Stormwater Quality Association Stormwater Best Management Practice Handbook. 2003.

8.3.1 Description

Infiltration trenches are defined as excavated trenches filled with coarse granular material; they collect stormwater runoff for temporary storage and infiltration. Typically, infiltration trenches and wells can capture only a small amount of runoff and therefore may be designed to capture the first flush of a runoff event rather than the full water quality volume (WQv). For this reason, they frequently are combined with another best management practice (BMP) such as a detention basin to control peak hydraulic flows. Infiltration trenches and wells can remove suspended solids, particulates, bacteria, organics, soluble metals, and nutrients through mechanisms of filtration, absorption, and microbial decomposition.

8.3.2 General Application

Typical applications of infiltration trenches include runoff treatments for residential lots and small commercial lots. In densely populated areas where undeveloped land area is scarce, infiltration basins may not be practical or effective. For these areas, infiltration trenches should become part of a developer's initial master plan of future development.

Infiltration trenches promote groundwater recharge. But, as with all infiltration practices, the possibility for groundwater contamination must be considered where groundwater is a source of drinking water. Infiltration trenches also do not filter coarse sediments.

Estimates indicate that infiltration trenches can remove 95 percent of suspended solids, 42 percent of phosphorous, and 42 percent of nitrogen in the stormwater (Claytor and Schueler, 1996). Do not use them to treat highly contaminated runoff.

8.3.3 Advantages

Reduce the volume of runoff from a drainage area

- Remove fine sediment, trace metals, nutrients, bacteria, and oxygen-demanding substances (organics)

- Reduce the size and cost of downstream stormwater control facilities and storm drain systems by infiltrating stormwater in upland areas
- Provide groundwater recharge and baseflow in nearby streams
- Reduce local flooding
- Useful where space is limited because of their narrow dimensions

8.3.4 Disadvantages

- Should not be installed until the entire contributing drainage area has been stabilized
- Risk failure because of improper siting, design, and lack of maintenance especially if pretreatment is not incorporated into the design
- Risk contaminating groundwater depending on soil conditions, land use in the watershed, and groundwater depth
- Not appropriate for industrial or commercial sites where release of large amounts or high concentrations of pollutants is possible
- Susceptible to clogging by sediment, necessitating frequent maintenance
- Inappropriate where surrounding soils have low permeability rates
- Effectively limited to small sites (2 acres or less).

8.3.5 Design Requirements and Considerations

Restrict the contributing drainage area to any infiltration trenches to 5 acres or less. Design trenches to provide a detention time of 6 to 72 hours for the water quality storm. Provide a minimum drainage time of 6 hours for satisfactory pollutant removal in the infiltration trench. Adjust the depth of the trench so that maximum drain time based on soil permeability is 72 hours for the total design infiltration volume.

Accommodate the volume and surface area of an infiltration trench to the water quality storm volume of runoff entering the trench from the contributing watershed and the permeability of the soil below the trench. Conservative estimates of soil infiltration rates are obtainable in the county soil surveys published by the U. S. Department of Agriculture or through field testing methods in accordance with Natural Resources Conservation Service (NRCS) guidance. If stormwater is conveyed to the trench as uniform sheet flow, maximize the length of the trench perpendicular to the flow direction. If stormwater is conveyed as channel flow, maximize the length of the trench parallel to the direction of flow. Calculate the appropriate bottom area of the trench using the following equation:

$$A = \frac{12(V)}{(P)(n)(t)}$$

Where

A =bottom area of the trench (square feet)

V =runoff volume to be infiltrated (cubic feet)

P = percolation rate of surrounding native soil (inches per hour)

N = void space fraction in the storage media (0.4 for clear stone)

t = retention time (maximum of 72 hours)

Create trench depths between 3 and 8 feet. Calculate a site-specific, maximally effective trench depth based on the soil percolation rate, aggregate soil space, and the trench storage time using the following equation:

$$D = \frac{(P)(t)}{(n)(12)}$$

Where

D = depth of the trench in feet

P = percolation rate of surrounding existing soil (inches per hour)

t = retention time (maximum of 72 hours)

n = void space fraction in the storage media (0.4 for clear stone)

Line the sides and bottom of the infiltration trench with geotextile fabric (filter fabric). Place a layer of nonwoven filter fabric 6 to 12 inches below the ground surface to prevent suspended solids from clogging the majority of the storage media. The filter fabric material must be compatible with the surrounding soil textures and application purposes. The cut width of the filter fabric must have sufficient material for a minimum 12-inch overlap. When overlaps are required between rolls, the upstream roll must lap a minimum of 2 feet over the downstream roll to provide a shingled effect. In place of filter fabric, cover the bottom of the infiltration trench with a 6-inch to 12-inch layer of clean sand.

The basic infiltration trench design uses stone aggregate in the top of the trench to provide storage. Fill the trench with clean washed stone (diameter of 1.5 to 2.5 inches) to provide a void space of 40 percent. Pea gravel or soil may be substituted for stone aggregate in the top 1 foot of the trench to improve sediment filtering and maximize pollutant removal at the top of the trench. Plant the infiltration trench with vegetation that can withstand periods of saturation and drought. Review and implement alternative storage media solutions case by case until adequate research and experience indicate how they perform.

An observation well located at the center of the trench to monitor water drainage from the system is required. The well should be 4-inch to 6-inch diameter PVC pipe anchored vertically to a footplate at the bottom of the trench. The well should have a lockable aboveground cap.

To remove as many suspended solids from the runoff as possible before they enter the trench, incorporate pretreatment such as grit chambers, swales with check dams, filter strips, or sediment forebays and traps as a component of infiltration trench design. Pretreatment helps maintain the infiltrating facility and extends periods between maintenance. Incorporate a bypass flow path in the design to convey high flows (storms larger than the water quality storm) around the trench. To preclude erosive concentrated flows, manage the overland flow path of the surface runoff that exceeds the capacity of the infiltration trench.

8.3.6 Other Design Criteria Considerations

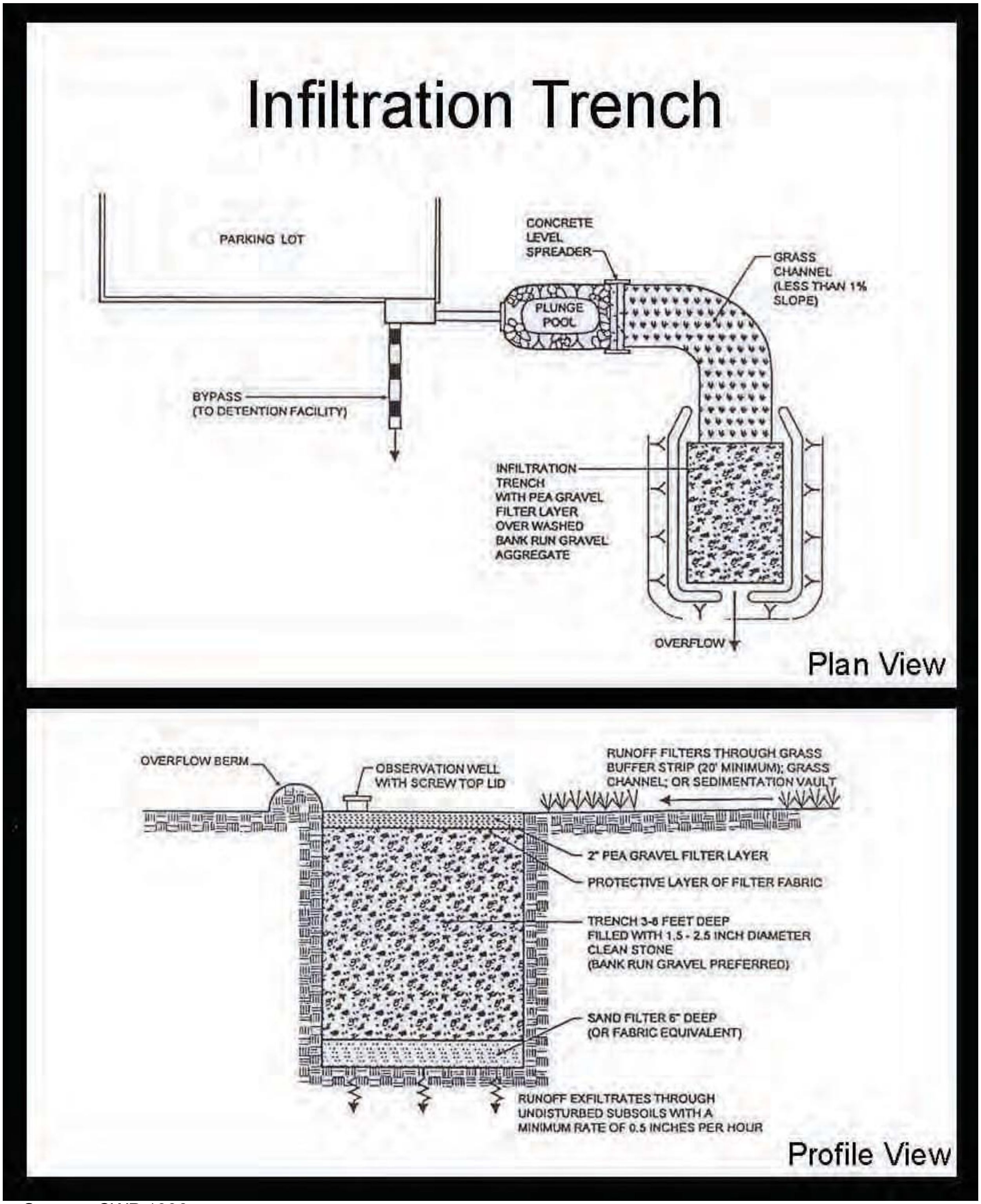
- Infiltration trenches should have an approximate depth of 3 to 8 feet. Design the volume of the trench to accommodate the water quality storm runoff per tributary acre within the depth of 3 to 8 feet. A standard length to width ratio is not recommended since the infiltration rate of the soil dictates the dimensions of the trench.
- A typical cross section for an infiltration trench includes a filter fabric lined trench, optional underdrain, and coarse granular material topped with clean compacted soil or gravel that can be planted with various species of vegetation. The clean stone diameters should be 1.5 to 2.5 inches. Install the optional underdrain to convey excess stormwater to the storm drain system. Install an observation well in conjunction with an infiltration trench. Install overflow devices so that storm events can bypass the infiltration trench to a safe point downstream.

- Locate infiltration trenches where the contributing drainage area is 5 acres or less, slopes are 5 percent or less, and surrounding soils have less than 40 percent clay and permeability rates of 0.5 to 2.0 inches per hour. The surrounding soil should also have a high, available, water holding capacity.
- Do not use limestone or shale as backfill material of the infiltration trench since they may cement over time. The filter fabric should be permeable enough for the trench to drain the design storm within 72 hours.
- Stabilize the contributing drainage area for erosion control before installing an infiltration trench. Use multiple pretreatment techniques together with infiltration trenches to eliminate potential clogging and to increase the lifespan of the trench. Install a 20-foot-minimum wide grass filter upslope of the infiltration trench to help remove coarse sediments from the stormwater. Figure 8.4 illustrates a typical infiltration trench.

8.3.7 Maintenance and Inspections

Following is a partial list of actions to upkeep infiltration trenches:

- Once the trench enters operation, inspect it after every major storm for the first few months to maintain proper stabilization and function. Record water levels in the observation well for several days to check trench drainage.
- Inspect for ponding after storm events to make sure the trench is not clogged.
- Frequently remove sediment from pretreatment facilities.
  - ◊ When ponding occurs at the surface or in the trench, undertake corrective maintenance immediately.
  - ◊ Remove grass clippings, leaves, and accumulated sediment routinely from the surface of the trench.
- Ponded water inside the trench (visible from the observation well) after 24 hours or several days following a storm event indicates the bottom of the trench is clogged. Remove and replace all of the stone aggregate and filter fabric or media.



Source: CWP 1996

FIGURE 8.4 - Infiltration Trench Plan and Profile Example
(for informational purposes only)

8.3.8 Design Example

To be completed at a later date.

8.4 BIORETENTION

Source: City of Lenexa, Kansas

Targeted Constituents

Constituent	Removal Effectiveness
Sediment	Medium
Nutrients	High
Trash	High
Metals	High
Bacteria	High
Oil and Grease	High
Organics	High

Legend (Removal Effectiveness)

High ● Medium ◐ Low ○

Source: California Stormwater Quality Association, 2003

8.4.1 Description

Bioretention is a best management practice (BMP) that filters, uptakes, and infiltrates stormwater runoff by way of the natural chemical, biological, and physical properties of plants, microbes, and soils (Programs & Planning Division, Department of Environmental Resources, Prince George's County, MD, Revised 2002) (CDM, 1989, 2001). The practice gets its name from the ability of the biomass within a small landscaped basin to retain the water quality volume (WQv) and remove nutrients and other pollutants from stormwater runoff (Programs & Planning Division, Department of Environmental Resources, Prince George's County, MD, Revised 2002). The runoff's velocity is reduced by passing the runoff over or through a pretreatment device and subsequently distributing it evenly along a ponding area (Urban Drainage and Flood Control District - Denver, Colorado, 2005). The WQv is allowed to infiltrate into the surrounding soil naturally or be collected by an underdrain system that discharges to the storm sewer system or directly to receiving water. Runoff in excess of the water quality storm is passed through or around the facility via an overflow structure.

Bioretention controls runoff close to the source. Unlike end-of-pipe BMPs, bioretention facilities are typically shallow depressions located in upland areas. The strategic, uniform distribution of bioretention facilities across a development site results in smaller, more manageable subwatersheds, and thus, will help in controlling runoff close to the source where it is generated to promote recharge. This is beneficial in that it reduces the amount of runoff that must be managed further downstream, thus reducing the cost and land area required for large regional BMPs (Programs & Planning Division, Department of Environmental Resources, Prince George's County, MD, Revised 2002).

8.4.2 General Application

Bioretention typically treats stormwater that has run over impervious surfaces at commercial, residential, and industrial areas (Urban Drainage and Flood Control District - Denver, Colorado, 2005). For example, bioretention is an ideal BMP to be used in median strips, parking lot islands, and landscaped swales. These areas can be designed or modified so that runoff is either diverted directly into the bioretention area or conveyed into the bioretention area by a curb and gutter collection system (Urban Drainage and Flood Control District - Denver, Colorado, 2005) (Office of Water, EPA, 1999).

Bioretention is usually most effective when used upland from inlets that receive sheet flow from graded areas. Bioretention can also be applied effectively where runoff is collected from impervious areas and discharged to a bioretention cell. To maximize treatment effectiveness, the site must be graded in such a way that minimizes erosive conditions as sheet flow is conveyed to the treatment area. Locations where a bioretention area can be readily incorporated into the site plan without further environmental damage are preferred. Furthermore, to effectively minimize sediment loading in the treatment area, bioretention only should be used in stabilized tributary areas (Urban Drainage and Flood Control District - Denver, Colorado, 2005) (Office of Water, EPA, 1999).

8.4.3 Advantages

- Bioretention facilities use minimal land area (1 to 15 percent of total tributary area) and can therefore be sited in locations that are unsuitable for other BMPs.
- Bioretention is easily incorporated in a BMP treatment train.
- Bioretention reduces peak runoff rate and volume from a site for small frequent storms and may reduce the total volume that must be managed further downstream (depending on the amount of retention).
- Bioretention has one of the highest nutrient and pollutant removal efficiencies of any BMP.
- Properly designed and maintained bioretention provides aesthetic enhancement. When aesthetic features are incorporated into bioretention designs, they encourage environmental stewardship and community pride. (Programs & Planning Division, Department of Environmental Resources, Prince George’s County, MD, Revised 2002).
- When constructed in areas with porous native soil, bioretention facilities can contribute to groundwater recharge.
- By intercepting runoff in bioretention areas near the source, the amount of the stormwater management infrastructure may be reduced, resulting in significant cost savings in site work (Programs & Planning Division, Department of Environmental Resources, Prince George’s County, MD, Revised 2002) (CDM, 2001).Bioretention facilities reduce the temperature of water discharged from the overall system (CDM, 2001).

8.4.4 Disadvantages

- Bioretention should not be installed until the entire tributary area has been stabilized; otherwise, silt from unstabilized areas can clog the bioretention facility.
- Bioretention is not a suitable BMP at locations where the wet season water table is within 1 to 2 feet of the ground surface and where the surrounding soil stratum is unstable. Too shallow of a water table can prevent runoff from draining completely through the bioretention soil mixture (CDM, 1989, 2001).
- Bioretention is not recommended for upland areas with slopes greater than 20 percent; otherwise, clogging may be a problem, particularly if the area receives runoff with high sediment loads. If clogging occurs, unclogging can be difficult (Office of Water, EPA, 1999).
- Bioretention is not recommended for areas where mature tree removal would be required (Office of Water, EPA, 1999). Existing trees should be incorporated into the bioretention facility where applicable.
- Flood control features are not easily incorporated into bioretention.
- Bioretention is most effective for tributary areas of less than 4 acres.
- Bioretention requires a specific soil matrix to provide a minimum saturated vertical hydraulic conductivity (See Appendix A for specification).

- Bioretention may not effectively remove pollutants immediately after construction. Pollutant removal efficiency increases as vegetation becomes established.

8.4.5 Design Requirements and Considerations

Design specifications for bioretention facilities are given in Appendix A.

One of the unique qualities of bioretention is the flexibility of design themes that a designer may employ when integrating into the site. Making multi-functional use of existing site constraints, bioretention can blend nicely with buffers, landscape berms, and environmental setback areas (Programs & Planning Division, Department of Environmental Resources, Prince George's County, MD, Revised 2002). Additionally, the layout of the bioretention area is determined after site constraints such as location of utilities, underlying soils, existing vegetation, and runoff are considered (Office of Water, EPA, 1999) (Programs & Planning Division, Department of Environmental Resources, Prince George's County, MD, Revised 2002). Figure 8.5 illustrates the composition of a sample bioretention facility. The following guidelines are to be considered when designing bioretention facilities:

- Bioretention facilities shall not be constructed within stream buffers or in areas adjacent to streams where sediment may be deposited during flood events.
- Bioretention facilities shall not be constructed until all tributary areas are permanently stabilized against erosion and sedimentation. Any discharge of sediment to the cell will require reconstruction of the cell to restore its defined performance.
- The bioretention facility shall be designed to capture the WQv. The WQv should filter through the facility's planting soil bed in 1 to 3 days.
- Recommended minimum dimensions are 15 feet wide by 40 feet long, although the preferred dimensions are 25 feet wide by 50 feet long, allowing enough space for a dense, randomly distributed area of plants and shrubs to become established while decreasing the chances of concentrated flow. Essentially, any facilities wider than 20 feet shall be twice as long as they are wide (Urban Drainage and Flood Control District - Denver, Colorado, 2005).
- The tributary area for a bioretention area shall be less than 4 acres. Multiple bioretention areas may be required for larger tributary areas (Office of Water, EPA, 1999). Inflow velocities to bioretention facilities shall be reduced to below erosive levels (generally 3 feet per second) upstream of the facility.

8.4.5.1 Excavation

- The bioretention facility can be excavated before final stabilization of the tributary area; however, the bioretention soil mixture and underdrain system shall not be placed until the entire tributary area has been stabilized. Any sediment from construction operations deposited in the bioretention facility shall be completely removed from the facility after all vegetation, including landscaping within the tributary area to the bioretention facility, has been established. The excavation limits shall then be final graded to the dimensions, side slopes, and final elevations as specified in the construction.
- Low ground-contact pressure equipment, such as excavators and backhoes, is preferred on bioretention facilities to minimize disturbance to established areas around the perimeter of the cell. No heavy equipment shall operate within the perimeter of a bioretention facility during underdrain placement, backfilling, planting, or mulching of the facility.
- Bioretention facility side slopes shall be excavated at 4:1 or flatter.

8.4.5.2 Underdrain or Outlet

The underdrain increases the ability of the soil to drain quickly and in so doing keeps the soil at an adequate aerobic state, allowing plants to flourish. The use of an underdrain system to provide a discharge point precludes the need for extensive geotechnical investigation. Underdrains are configured in many different ways and typically include a gravel/stone “blanket” encompassing a horizontal, perforated discharge pipe. An aggregate can be used to protect the underdrain from clogging (Programs & Planning Division, Department of Environmental Resources, Prince George’s County, MD, Revised 2002).

- Design the underdrain system with the following components: a 4-inch minimum perforated pipe system with an 8-inch gravel bed. Filter fabric shall be placed around the gravel bed to separate it from the planting soil bed. The pipe shall have perforations between 0.25 and 0.375 inches diameter, spaced at 6-inch centers, with a minimum of 4 holes per row. The pipe(s) shall be placed with one header and several branches or several headers such that the maximum flow path has a length of 5 feet when viewed in plan. Maintain a minimum grade of 0.5 percent. See specification in Appendix A for additional underdrain system design criteria.
- Provide at least one cleanout per run and every 50 feet or less.
- Connect the underdrain system to the conventional stormwater management system, or daylight it to a suitable nonerosive outfall.
- A valve or cap at the end of the underdrain system may be provided to allow for the possibility of closing off the underdrain. This will enable longer retention times, which will allow plants more opportunity for nutrient uptake and more groundwater recharge.

After placing the underdrain and aggregate and before placing the bioretention soil mixture (BSM), the bottom of the excavation shall be rototilled to a minimum depth of 6 inches to alleviate any compaction of the facility bottom. Any ponded water shall be removed from the bottom of the facility, and the soil shall be friable before rototilling. The rototilling shall not be done where the soil supports the aggregate bed underneath the underdrain.

8.4.5.3 Overflow

The overflow component of the bioretention system consists of the gravel underdrain system, an aggregate overflow curtain drain, and a high-flow overflow structure (Programs & Planning Division, Department of Environmental Resources, Prince George’s County, MD, Revised 2002). In a residential setting, overflow usually does not present a problem for two reasons: (1) the tributary area and facility capacity are relatively small, and (2) the system is located within grassy areas that provide a safe, nonerosive surface for any overflow conditions that may arise. Additionally, residential bioretention facilities are typically designed off line and already incorporate a safe overland flow path. In commercial or industrial settings, design for overflow is more critical. Often, facilities in commercial settings are incorporated into the parking lot landscape islands. The paved surfaces flowing to the facilities can generate large quantities of runoff. Designers are required to provide a safe discharge point (Programs & Planning Division, Department of Environmental Resources, Prince George’s County, MD, Revised 2002).

- Bioretention can be designed to be off line or on line of the existing stormwater management system (Office of Water, EPA, 1999). If the system is off line, design the overflow to convey peak discharge of the WQv and set it above the shallow ponding limit. If the facility is on line, design the high flow overflow as a conventional stormwater control structure or channel. Connect the overflow structure to the site stormwater management system, or outfall to a suitable nonerosive location.
- The high flow overflow system is usually a yard drain catch basin, but any number of conventional management practices may be used, including an open vegetated or stabilized channel.
- Bioretention facilities shall be designed so that runoff flows from storm events greater than the water quality event, up to and including the 1 percent event, safely pass through or around the facility. If the 1 percent event is to pass through the facility, the maximum velocity shall be kept below 3 feet per second to avoid erosion of the soil matrix. If facilities are designed with a bypass, it shall be designed to safely pass runoff flows from events up to and including the 1 percent event. At a minimum, all facility embankments shall be protected from failure during the 1 percent event.

8.4.5.4 Aggregate

An aggregate, which provides a greater porosity and is less likely to clog, is preferred (Programs & Planning Division, Department of Environmental Resources, Prince George's County, MD, Revised 2002).

It is recommended to have an aggregate layer around the perforated pipe to facilitate drainage. Refer to the specification in Appendix A.

8.4.5.5 Sand Bed

The sand bed is an optional feature that underlies the planting soil bed and allows water to drain from the planting soil bed into the surrounding soil. It provides additional filtration and allows aeration of the planting soil bed (Office of Water, EPA, 1999).

8.4.5.6 Planting Soil Bed

The soil characteristics are critical for the proper operation of the bioretention facility. The planting soil, called the BSM, provides the water and nutrients for the plants to sustain growth (Programs & Planning Division, Department of Environmental Resources, Prince George's County, MD, Revised 2002). The BSM is a mixture of organic mulch, planting soil, and sand. To enhance nutrient uptake, the soil must have a combination of chemical and physical properties to support a diverse microbial community.

- The planting soil shall have a minimum depth of approximately 2.5 feet to provide adequate moisture capacity and to create space for the root system of the plants. Root balls of many trees will require additional depths (Programs & Planning Division, Department of Environmental Resources, Prince George's County, MD, Revised 2002). Planting soil shall be 4 inches deeper than the bottom of the largest root ball and a maximum of 4 feet altogether. Planting soil depths greater than 4 feet may require additional construction practices, such as shoring measures (Urban Drainage and Flood Control District - Denver, Colorado, 2005) (Office of Water, EPA, 1999).
- The BSM shall be free of stones, stumps, roots, or other weedy material over 1 inch in diameter, excluding the mulch. Brush or seeds from noxious weeds shall not be present in the solids. Refer to the specification in Appendix A.

8.4.5.7 Organic or Mulch Layer

The organic layer (mulch) protects the soil bed from erosion, retains moisture in the plant zone, provides a medium for biological growth and decomposition of organic matter, and filters pollutants (Programs & Planning Division, Department of Environmental Resources, Prince George's County, MD, Revised 2002).

- Following placement of any trees and shrubs, the ground cover and/or mulch shall be established at an appropriate depth during the establishment period. Ground cover such as grasses or legumes can be planted at the beginning of the growing season (Urban Drainage and Flood Control District - Denver, Colorado, 2005). Mulching shall be complete within 24 hours after the trees and shrubs are planted to reduce the potential of silt accumulation on the surface (Urban Drainage and Flood Control District - Denver, Colorado, 2005).
- Pine mulch and wood chips are not acceptable in the mulch layer because they are displaced during storm events (Programs & Planning Division, Department of Environmental Resources, Prince George's County, MD, Revised 2002). Grass clippings are not allowed in the mulch layer. Refer to the specification in Appendix A.

8.4.5.8 Plant Materials

The role of plant species in the bioretention concept is to bind nutrients and other pollutants by plant uptake, to remove water through evapotranspiration, and to create pathways for infiltration through root development and plant growth. Root growth provides a media that fosters bacteriologic growth, which in turn develops a healthy soil structure. Proper selection and installation of plant material is key to the success of the bioretention system.

- The designer should assess aesthetics, site layout, natural function, and maintenance requirements when selecting and placing plant species (Office of Water, EPA, 1999).
- Native grasses and other various local ground covers can be incorporated into a bioretention planting scheme. Trees and shrubs are also beneficial in wider facilities (minimum of 15 to 20 feet) because they create shade. Shade helps reduce runoff temperature and can be seen as an amenity in applications such as parking lots.
- See specification in Appendix A for appropriate plant materials.

8.4.5.9 Ponding Area

The ponding area provides temporary surface storage of stormwater runoff before it filters through the soil bed and facilitates the evaporation of a portion of the runoff (Office of Water, EPA, 1999) (Programs & Planning Division, Department of Environmental Resources, Prince George's County, MD, Revised 2002). The ponding area (A_p) is the actual footprint of the Bioretention cell. Settling of the particulates occurs in the ponding area and provides an element of pretreatment. Ponding design depths shall be kept to a minimum to reduce hydraulic overload of in situ soils/soil medium and to maximize the surface area to facility depth ratio (Programs & Planning Division, Department of Environmental Resources, Prince George's County, MD, Revised 2002). The ponding area shall have a maximum depth of 12 inches. However, a depth of 3 to 4 inches is preferable (Urban Drainage and Flood Control District - Denver, Colorado, 2005).

8.4.5.10 Pretreatment

The best method of capturing and treating runoff is to allow the water to sheetflow into the facility over grassed areas to reduce inflow velocity and to reduce the load of coarse sediment entering the bioretention area (Programs & Planning Division, Department of Environmental Resources, Prince George's County, MD, Revised 2002). When site constraints or space limitations impede sheetflow, flow entrances shall be created that reduce the velocity of the water. Possible Pretreatment alternatives include:

- Vegetated Pretreatment Strip. Runoff enters the bioretention area as sheet flow through the vegetated pretreatment strip, which can be planted with native grass or turf-forming grass. The filter strip reduces incoming runoff velocity and filters particulates from the runoff (Office of Water, EPA, 1999). Several factors determine the length in the direction of flow of the vegetated pretreatment strip, including size and imperviousness of the tributary area and filter strip slope. If a vegetated pretreatment strip is used, its length shall be 10 feet at a minimum. See Table 8.2 for vegetated pretreatment strip sizing guidelines.
- Vegetated Pretreatment Channel. For sites where concentrated or channelized runoff enters the bioretention system, such as through a slotted curb opening, a vegetated channel with an aggregate is the preferred pretreatment method. This channel can also be planted with native grass or turf-forming grass. The length in the direction of flow of the vegetated pretreatment channel depends on the tributary area, land use, and channel slope. When a vegetated channel is used, the minimum length shall be 25 feet. See Table 8.3 for vegetated channel sizing guidelines.
- In the case of parking lot landscape islands, curb cuts protected with energy dissipaters such as landscape stone or surge stone can be used. It is important to note that entrances of this type will tend to become obstructed with sediment and trash that settles out at lower velocities. This is not a problem as long as routine parking lot maintenance is performed (Programs & Planning Division, Department of Environmental Resources, Prince George's County, MD, Revised 2002).
- Baffle boxes or other pretreatment devices can be used as a pretreatment to flow entering a bioretention facility from a piped system. This form of pretreatment serves to settle out solids and slow the velocity of

flow. Cisterns placed at the bottoms of roof downspouts can be used to slow the velocity of runoff coming from rooftops and direct it to landscaped swale.

8.4.6 Maintenance and Inspections

By design, bioretention does not require intense maintenance efforts. Proper maintenance will increase the expected life span of the facility and will improve aesthetics (Programs & Planning Division, Department of Environmental Resources, Prince George's County, MD, Revised 2002).

The primary maintenance requirement for bioretention areas is that of inspection and repair or replacement of the treatment area's components. Generally, this involves nothing more than the routine periodic maintenance that is required of any landscaped area. Plants that are appropriate for the site, climatic, and watering conditions should be selected for use in the bioretention cell. Appropriately selected plants will aid in reducing fertilizer, pesticide, water, and overall maintenance requirements. Bioretention system components should blend over time through plant and root growth, organic decomposition, and the development of a natural soil horizon. These biologic and physical processes over time will lengthen the facility's life span and reduce the need for extensive maintenance (Urban Drainage and Flood Control District - Denver, Colorado, 2005).

Routine inspections for areas of standing water and corrective measures to restore proper infiltration rates are necessary to prevent creating mosquito and other vector habitat. In addition, bioretention areas are susceptible to invasion by aggressive plant species such as cattails, which increase the chances of water standing and subsequent vector production if not routinely maintained (Urban Drainage and Flood Control District - Denver, Colorado, 2005).

Bioretention maintenance resembles that of any maintained landscaping area. Following is a partial list of maintenance actions to upkeep bioretention:

- Inspect biannually for erosion of pretreatment and bioretention areas.
- Mulch as needed to cover bare soil. Spot mulching may be adequate when there are random void areas (Urban Drainage and Flood Control District - Denver, Colorado, 2005) (Office of Water, EPA, 1999). The old mulch shall be removed before the new mulch is distributed. Old mulch shall be disposed of properly (Office of Water, EPA, 1999).
- Annually inspect vegetation to evaluate its health and remove any dead or severely diseased vegetation (Office of Water, EPA, 1999).
- If stressed vegetation is present, further soil investigation is needed. If soil is contaminated, full or partial soil replacement in the planting zone is required.
- Diseased vegetation shall be treated as necessary using preventative and low-toxic measures to the extent possible (Office of Water, EPA, 1999).
- Annually inspect overflow devices.
- Remove trash and sediment as necessary (Programs & Planning Division, Department of Environmental Resources, Prince George's County, MD, Revised 2002).
- Aerate periodically.

8.4.7 Design Example

Below is a bioretention facility design example. These procedures follow the steps outlined in the Design Procedure Form: Bioretention, Main Worksheet. When using the worksheet in electronic form, manually enter values in green.

Example: Design a bioretention facility to treat runoff from the water quality rainfall event for the Kansas City Metropolitan Area (1.37 inches) coming off a ½-acre paved parking lot.

I. Basin Water Quality Storage Volume

Step 1 - Enter the tributary area to the bioretention facility (A_T).

Step 2 - Calculate the WQv using the methodology in Section 6 of this manual.

IIa. Pretreatment

Step 1 - Specify the type of inflow to the facility as either sheetflow or concentrated/channelized flow.

Step 2 - Specify the type of pretreatment to use (vegetated filter strip, vegetated channel or other pretreatment device).

Step 3 - Proceed to Part IIb, IIc, or IId for design guidance on different pretreatment options.

IIb. Vegetated Pretreatment Strip

Step 1 - Specify the type of land cover of the contributing area to the facility.

Step 2 - Enter the maximum inflow approach length ($L_{approach}$). This is the maximum length that runoff will flow across the parking lot before hitting the bioretention facility.

Step 3 - Enter the average slope of the vegetated filter strip (S_{f5}). This slope should not exceed 6 percent.

Step 4 - Determine the minimum required length for the filter strip (L_{fs}) from Table 8.2.

IIc. Vegetated Pretreatment Channel

Step 1 - Enter the percent imperviousness of the contributing area to the facility (% imp).

Step 2 - Enter the average slope of the vegetated channel (S_{vc}). This slope should not exceed 6 percent.

Step 3 - Determine the minimum required length for the vegetated channel (L_{vc}) from Table 8.3.

IId. Other Pretreatment Devices

Other methods of pretreatment may be used upstream of a bioretention facility to settle out suspended solids and reduce runoff velocity. Several proprietary devices are available that will achieve these results. Most of these devices are installed below ground and accept inflow from a piped stormwater management system or from surface sheetflow via drop inlets. These devices should be selected and sized based on site-specific conditions for each project and according to manufacturer instructions.

III. Planting Soil Bed and Ponding Area

Step 1 - Enter the planting soil bed depth (d_f). This depth can range from 2.5 feet to 4 feet. Soil bed depths greater than 4 feet may require additional construction practices such as shoring measures.

Step 2 - Enter the coefficient of permeability for the soil bed (k). The soil bed mixture should be tested before construction of the facility to ensure that it meets the desired permeability. This value should be at least 1 ft/day.

Step 3 - Enter the maximum ponding depth in the facility (h_{max}). This depth should be between 3 and 12 inches.

Step 4 - Calculate the average height of water above the bioretention bed (h_{avg}) as half the depth set in Step 3.

$$H_{avg} = H_{max}/2$$

Step 5 - Enter the time required for the WQv to filter through the planting soil bed (t_f). A time of 3 days is recommended.

Step 6 - Calculate the required filter bed surface area (A_f). See equation derivation on the Variable Dictionary sheet of the Bioretention Design Procedure Form.

$$A_f = (WQv * d_f)/[k * t_f * (h + d_f)]$$

Step 7 - Calculate the approximate filter bed length (L_f). Optimally the facility will be twice as long as it is wide. The facility length should be at least 40 feet.

Step 8 - Calculate the approximate filter bed width (W_f). This dimension should be approximately half the filter bed length, and should be at least 15 feet.

Step 9 - Calculate the Ponding Area (A_p).

IV. Underdrain

Step 1 - Set the underdrain pipe diameter (D_U). This value should be at least 4 inches.

Step 2 - Determine the depth of the gravel blanket (Z_{gravel}) around the underdrain pipe. This depth should be no less than 8 inches and should be at least 2 inches greater than the underdrain pipe diameter.

Step 3 - Set underdrain perforation diameter to 0.375 inches.

Step 4 - Set the longitudinal center-to-center underdrain perforation spacing (S_{perf}) as 6 inches.

Step 5 - Set the number of perforations per row (n_{perf}) (around the circumference of the underdrain pipe). This number should be at least 4.

Step 6 - Determine whether or not it is necessary to include transverse collector pipes that run perpendicular to and connect to the main underdrain pipe. If the bioretention facility width is greater than 10 feet, it will be necessary to include transverse collector pipes or additional parallel pipes.

Step 7 - Set the underdrain transverse collector pipe spacing (S_U) center-to-center. This distance should be no more than 10 feet.

Step 8 - Determine the number of transverse collector pipes (n_{pipe}) to cover the length of the facility based on the spacing from Step 8.

Step 9 - Ensure that the grade for all underdrain pipes (G_{pipe}) is at least 0.5 percent.

Step 10 -Ensure that one cleanout is provided at the end of each pipe run.

V. Overflow

The bioretention overflow shall be designed to safely pass runoff flows from events up to and including the 1 percent event unless the facility is designed with a bypass around the facility for larger storm events. If the 1-percent event is to pass through the facility, the maximum velocity shall be kept below 3 feet per second to avoid erosion of the soil matrix. If facilities are designed with a bypass, it shall be designed to safely pass runoff flows from events up to and including the 1 percent event. The overflow can be designed as a vegetated or stabilized channel or a yard inlet catch basin. Vegetated or stabilized channel overflows shall be designed using one of the methods presented in APWA Section 5603 and shall conform to the design criteria presented in APWA Section 5607. Methods presented in APWA Section 5604 shall be used for overflow inlet design.

VI. Vegetation

Enter a description of the mix and density of vegetation that will be planted in the bioretention facility. Follow guidance given in Appendix A of this manual. It is beneficial to plant variable types and species of plants in a bioretention facility. Such variability prevents single-species susceptibility to disease and insect infestation and provides a more aesthetic appearance. Native species should be used because they are more likely to thrive in the local climate. A minimum of three native species of shrubs and three native species of plants is recommended. Plants should also be selected for their ability to withstand extended dry conditions (which are likely to occur in parking lot island bioretention facilities) and periodic inundation.

TABLE 8.2
Vegetated Pretreatment Strip Sizing Guidance

Parameter	Impervious Parking Lots				Residential Lawns				Notes
Maximum Inflow Approach Length (feet)	35		75		75		150		
Filter Strip Slope	≤2%	≥2%	≤2%	≥2%	≤2%	≥2%	≤2%	≥2%	Maximum Slope = 6%
Filter Strip Minimum Length (feet)	10	15	20	25	10	12	15	18	

TABLE 8.3
Vegetated Pretreatment Channel Sizing Guidance for a 1.0-Acre Tributary Area

Parameter	≤33% Impervious		Between 34% and 66% Impervious		≥67% Impervious		Notes
Channel Slope	≤2%	≥2%	≤2%	≥2%	≤2%	≥2%	Maximum Slope = 6%
Grass Channel Minimum Length (feet)	25	40	30	45	35	50	Assumes bottom width is 2 feet

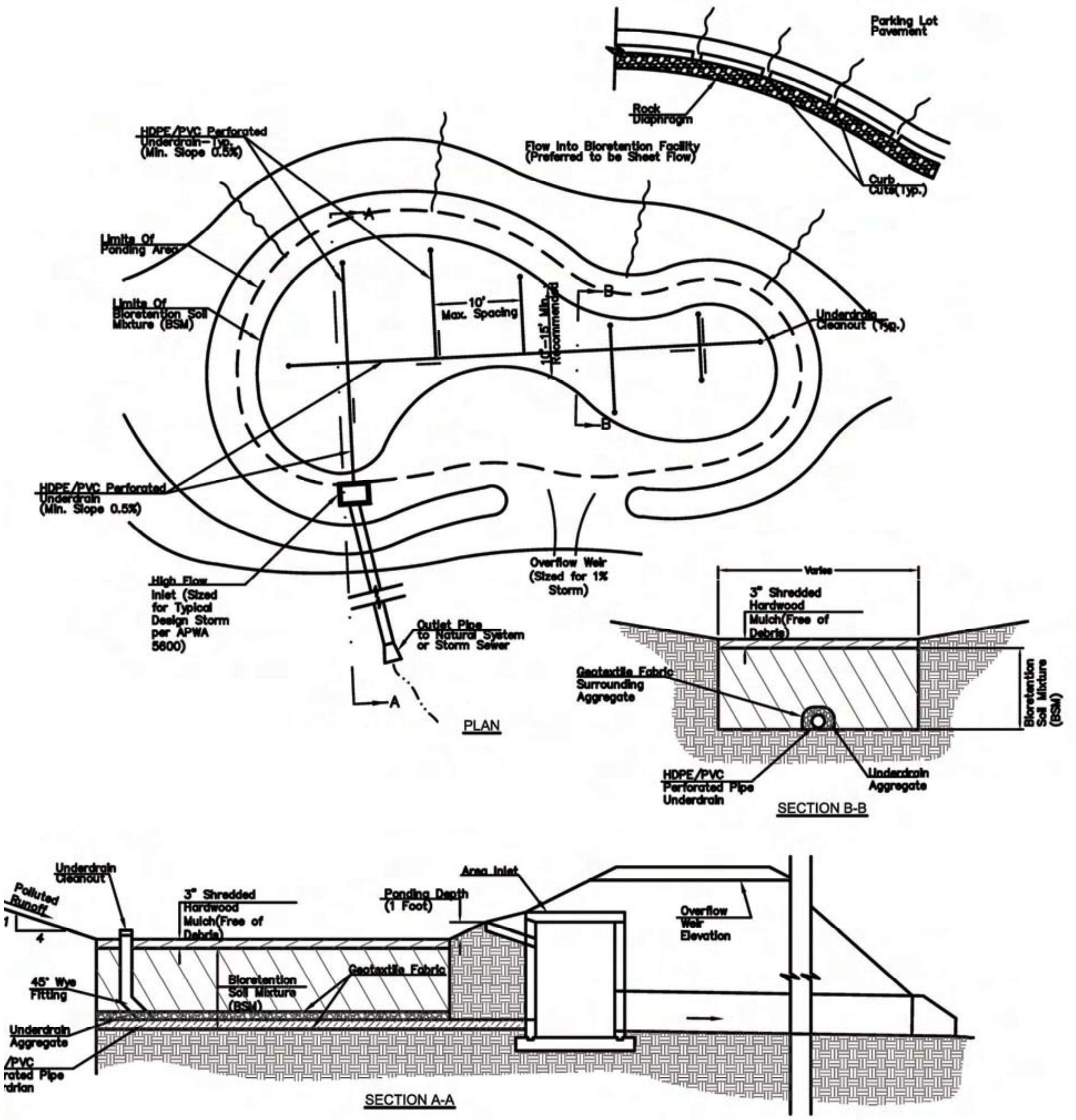


FIGURE 8.5 - Bioretention Plan and Profile

Design Procedure Form: Bioretention
Main Worksheet

Designer: ____________________
Checked By: ____________________
Company: ____________________
Date: ____________________
Project: ____________________
Location: ____________________

I. Water Quality Volume	
Step 1) Tributary area to bioretention area, A_T (ac)	A_T (ac) = 0.55
Step 2) Calculate WQv using methodology in Section 6	WQv (cu-ft) = 2380
IIa. Pretreatment	
Step 1) Specify type of inflow to Bioretention facility: Type 1 = sheet flow Type 2 = concentrated or channelized	Inflow type = 1
Step 2) Pretreatment	Vegetated Pretreatment Strip
Step 3) Proceed to Part IIb, IIc, or IId for design guidance on different pretreatment options	
IIb. Vegetated Pretreatment Strip	
Step 1) Type of land cover of contributing area: Type 1 = Impervious (i.e., parking lot) Type 2 = Pervious (i.e., residential lawn)	Land cover type = 1
Step 2) Maximum inflow approach length, $L_{approach}$ (ft)	$L_{approach}$ (ft) = 75
Step 3) Average slope of pretreatment strip, S_{fs} (%) (Maximum slope of 6%)	S_{fs} (%) = 1.5
Step 4) Vegetated pretreatment strip minimum length, L_{fs} (ft), from Table 8.2	L_{fs} (ft) = 20
IIc. Vegetated Pretreatment Channel	
Step 1) Percent imperviousness of contributing area, % imp	% imp = NA
Step 2) Average slope of vegetated channel, S_{vc} (%) (Maximum slope of 6%)	S_{vc} (%) = NA
Step 3) Vegetated pretreatment channel minimum length, L_{vc} (ft), from Table 8.3	L_{vc} (ft) = NA
IId. Other Pretreatment Devices	
Other methods of pretreatment may be utilized upstream of a bioretention facility to settle out suspended solids and reduce runoff velocity. Several proprietary devices are available that will achieve these results. Most such devices install below ground and accept inflow from a piped stormwater management system or from surface sheet flow via drop inlets. These devices should be selected and sized based on site-specific conditions for each project.	

Design Procedure Form: Bioretention
Main Worksheet

Designer: ______________________
Checked By: ______________________
Company: ______________________
Date: ______________________
Project: ______________________
Location: ______________________

III. Planting Soil Bed and Ponding Area

Step 1) Planting bed soil depth, d_f (ft) (d_f should be between 2.5 feet and 4 feet).	d_f (ft) =	3
Step 2) Coefficient of permeability for planting soil bed, k (ft/day) (k should be at least 1 ft/ day)	k (ft/ day) =	1.3
Step 3) Maximum ponding depth, h_{max} (ft) (h_{max} should be between 0.25 ft and 1.0 ft).	h_{max} (ft) =	1
Step 4) Average height of water above bioretention bed, havg (ft) $h_{avg} = h_{max}/2$	h_{avg} (ft) =	0.5
Step 5) Time required for WQv to filter through the planting soil bed, t_f (days) (t_f of 1 to 3 days is recommended)	t_f (days) =	2
Step 6) Required filter bed surface area, A_f (ft^2) $A_f = (WQv*d_f)/[k*t_f*(h_{avg}+df)]$	A_f (ft^2) =	785
Step 7) Approximate filter bed length, L_f (ft), assuming a length to width ratio of 2:1 (L_f should be at least 40 ft)	L_f (ft) =	40
Step 8) Approximate filter bed width, W_f (ft), assuming a length to width ratio of 2:1 (W_f should be at least 15 feet, and optimally half of L_f)	W_f (ft) =	20
Step 9) Required Ponding Area, A_p (sf) $Ap = WQv/h_{max}$	Ap (ft^2) =	2380

Design Procedure Form: Bioretention
Main Worksheet

Designer: ____________________
Checked By: ____________________
Company: ____________________
Date: ____________________
Project: ____________________
Location: ____________________

IV. Underdrain		
Step 1) Underdrain pipe diameter, D_U (in) (D_U should be at least 4 inches)	D_U (in) =	6
Step 2) Depth of gravel blanket, Z_{gravel} (in.) (Z_{gravel} should be at least 8 inches, and at least 2 inches greater than D_U)	Z_{gravel} (in) =	8
Step 3) Set underdrain perforation diameters to 0.375 inches.	D_{perf} (in) =	0.375
Step 4) Longitudinal center-to-center underdrain perforation spacing, S_{perf} (in)	S_{perf} (in) =	6
Step 5) Number of perforations per row (around circumference of underdrain), n_{perf} (n_{perf} should be at least 4)	n_{perf} =	5
Step 6) Are transverse collector pipes required perpendicular to main pipe? (Yes or no) (Yes, if width of bioretention area is greater than 10 feet)		Yes
Step 7) Underdrain transverse collector pipe spacing center-to-center, S_U (ft) (S_U should be a maximum of 10 ft)	S_U (ft) =	N/A
Step 8) Required number of underdrain transverse collector pipes, n_{pipe}	n_{pipe} =	0
Step 9) Pipe grade, Gpipe (%), for main pipe and transverse collector pipes (G_{pipe} should be at least 0.5%)	G_{pipe} (%) =	0.5
Step 10) Providing at least one cleanout per pipe run? (Yes or No)		Yes

V. Overflow

The bioretention overflow shall be designed to safely pass runoff flows from events up to and including the 1 percent event unless the facility is designed with a bypass around the facility for larger storm events. If the 1-percent event is to pass through the facility, the maximum velocity shall be kept below 3 feet per second to avoid erosion of the soil matrix. If facilities are designed with a bypass, it shall be designed to safely pass runoff flows from events up to and including the 1 percent event. The overflow shall be designed as a vegetated or stabilized channel of a yard inlet catch basin. Vegetated or stabilized channels shall be designed using one of the methods presented in APWA Section 5603 and shall conform to the design criteria presented in APWA Section 5607. Methods presented in APWA Section 5604 shall be used for inlet design.

Design Procedure Form: Bioretention
Main Worksheet

Designer: ______________________
Checked By: ______________________
Company: ______________________
Date: ______________________
Project: ______________________
Location: ______________________

V. Vegetation

Describe mix and density of vegetation to be placed in the bioretention facility. Follow specifications given under Plant Materials in Appendix A. It is beneficial to plant variable types and species of plants in a bioretention facility. Such variability prevents single-species susceptibility to disease and insect infestation and provides a more aesthetic appearance. Native species should be used because they are more likely to thrive in the local climate. A minimum of three native species of shrubs and three native species of trees recommended. Plants should also be selected for their ability to withstand extended dry conditions (which are likely to occur in parking lot island bioretention facilities) and periodic inundation.

Design Procedure Form: Bioretention
Main Worksheet

Designer: ______________________
Checked By: ______________________
Company: ______________________
Date: ______________________
Project: ______________________
Location: ______________________

I. Water Quality Volume

Step 1) Tributary area to bioretention area, A_T (ac) — A_T (ac) = ________

Step 2) Calculate WQv using methodology in Section 6 — WQv (cu-ft) = ________

IIa. Pretreatment

Step 1) Specify type of inflow to Bioretention facility: — Inflow type = ________
Type 1 = sheet flow
Type 2 = concentrated or channelized

Step 2) Pretreatment — ________

Step 3) Proceed to Part IIb, IIc, or IId for design guidance on different pretreatment options

IIb. Vegetated Pretreatment Strip

Step 1) Type of land cover of contributing area: — Land cover type = ________
Type 1 = Impervious (i.e., parking lot)
Type 2 = Pervious (i.e., residential lawn)

Step 2) Maximum inflow approach length, $L_{approach}$ (ft) — $L_{approach}$ (ft) = ________

Step 3) Average slope of pretreatment strip, S_{fs} (%) — S_{fs} (%) = ________
(Maximum slope of 6%)

Step 4) Vegetated pretreatment strip minimum length, L_{fs} (ft), from Table 8.2 — L_{fs} (ft) = ________

IIc. Vegetated Pretreatment Channel

Step 1) Percent imperviousness of contributing area, % imp — % imp = ________

Step 2) Average slope of vegetated channel, S_{vc} (%) — S_{vc} (%) = ________
(Maximum slope of 6%)

Step 3) Vegetated pretreatment channel minimum length, L_{vc} (ft), from Table 8.3 — L_{vc} (ft) = ________

IId. Other Pretreatment Devices

Other methods of pretreatment may be utilized upstream of a bioretention facility to settle out suspended solids and reduce runoff velocity. Several proprietary devices are available that will achieve these results. Most such devices install below ground and accept inflow from a piped stormwater management system or from surface sheet flow via drop inlets. These devices should be selected and sized based on site-specific conditions for each project.

Design Procedure Form: Bioretention
Main Worksheet

Designer: ______________________
Checked By: ______________________
Company: ______________________
Date: ______________________
Project: ______________________
Location: ______________________

III. Planting Soil Bed and Ponding Area

Step 1) Planting bed soil depth, d_f (ft) — d_f (ft) = ________
(d_f should be between 2.5 feet and 4 feet).

Step 2) Coefficient of permeability for planting soil bed, k (ft/day) — k (ft/ day) = ________
(k should be at least 1 ft/ day)

Step 3) Maximum ponding depth, h_{max} (ft) — h_{max} (ft) = ________
(h_{max} should be between 0.25 ft and 1.0 ft).

Step 4) Average height of water above bioretention bed, havg (ft) — h_{avg} (ft) = ________
$h_{avg} = h_{max}/2$

Step 5) Time required for WQv to filter through the planting soil bed, t_f (days) — t_f (days) = ________
(t_f of 1 to 3 days is recommended)

Step 6) Required filter bed surface area, A_f (ft^2) — A_f (ft^2) = ________
$A_f = (WQv*d_f)/[k*t_f*(h_{avg}+df)]$

Step 7) Approximate filter bed length, L_f (ft), assuming a length to width ratio of 2:1 — L_f (ft) = ________
(L_f should be at least 40 ft)

Step 8) Approximate filter bed width, W_f (ft), assuming a length to width ratio of 2:1 — W_f (ft) = ________
(W_f should be at least 15 feet, and optimally half of L_f)

Step 9) Required Ponding Area, A_p (sf) — Ap (ft^2) = ________
$Ap = WQv/h_{max}$

Design Procedure Form: Bioretention
Main Worksheet

Designer: ____________________
Checked By: ____________________
Company: ____________________
Date: ____________________
Project: ____________________
Location: ____________________

IV. Underdrain

Step 1) Underdrain pipe diameter, D_U (in) (D_U should be at least 4 inches)	D_U (in) = ______
Step 2) Depth of gravel blanket, Z_{gravel} (in.) (Z_{gravel} should be at least 8 inches, and at least 2 inches greater than D_U)	Z_{gravel} (in) = ______
Step 3) Set underdrain perforation diameters to 0.375 inches.	D_{perf} (in) = ______
Step 4) Longitudinal center-to-center underdrain perforation spacing, S_{perf} (in)	S_{perf} (in) = ______
Step 5) Number of perforations per row (around circumference of underdrain), n_{perf} (n_{perf} should be at least 4)	n_{perf} = ______
Step 6) Are transverse collector pipes required perpendicular to main pipe? (Yes or no) (Yes, if width of bioretention area is greater than 10 feet)	______
Step 7) Underdrain transverse collector pipe spacing center-to-center, S_U (ft) (S_U should be a maximum of 10 ft)	S_U (ft) = ______
Step 8) Required number of underdrain transverse collector pipes, n_{pipe}	n_{pipe} = ______
Step 9) Pipe grade, Gpipe (%), for main pipe and transverse collector pipes (G_{pipe} should be at least 0.5%)	G_{pipe} (%) = ______
Step 10) Providing at least one cleanout per pipe run? (Yes or No)	

V. Overflow

The bioretention overflow shall be designed to safely pass runoff flows from events up to and including the 1 percent event unless the facility is designed with a bypass around the facility for larger storm events. If the 1-percent event is to pass through the facility, the maximum velocity shall be kept below 3 feet per second to avoid erosion of the soil matrix. If facilities are designed with a bypass, it shall be designed to safely pass runoff flows from events up to and including the 1 percent event. The overflow shall be designed as a vegetated or stabilized channel of a yard inlet catch basin. Vegetated or stabilized channels shall be designed using one of the methods presented in APWA Section 5603 and shall conform to the design criteria presented in APWA Section 5607. Methods presented in APWA Section 5604 shall be used for inlet design.

Design Procedure Form: Bioretention
Main Worksheet

Designer: ______________________
Checked By: ______________________
Company: ______________________
Date: ______________________
Project: ______________________
Location: ______________________

V. Vegetation

Describe mix and density of vegetation to be placed in the bioretention facility. Follow specifications given under Plant Materials in Appendix A. It is beneficial to plant variable types and species of plants in a bioretention facility. Such variability prevents single-species susceptibility to disease and insect infestation and provides a more aesthetic appearance. Native species should be used because they are more likely to thrive in the local climate. A minimum of three native species of shrubs and three native species of trees recommended. Plants should also be selected for their ability to withstand extended dry conditions (which are likely to occur in parking lot island bioretention facilities) and periodic inundation.

Variable Dictionary

Variable	Units	Definition
A_f	ft^2	Required filter bed surface area
A_T	ac	Tributary area to Bioretention Facility
d_f	ft	Planting bed soil depth
D_{perf}	in	Underdrain perforation diameter
D_U	in	Underdrain pipe diameter
G_{pipe}	%	Pipe grade for main pipe and transverse collector pipes
h_{avg}	ft	Average ponding depth above soil bed
h_{max}	ft	Maximum ponding depth above soil bed
k	ft/day	Coefficient of permeability for planting soil bed
$L_{approach}$	ft	maximum inflow approach length to bioretention facility
L_f	ft	Approximate filter bed length
L_{fs}	ft	Minimum length of vegetated filter strip
L_{vc}	ft	Minimum length of vegetated channel
n_{perf}	none	Number of perforations per row (around circumference of underdrain pipe)
n_{pipe}	none	Number of underdrain transverse collector pipes
% Imp	%	Percent imperviousness of contributing area
S_{fs}	%	Average slope of vegetated filter strip
S_{perf}	in	Longitudinal center-to-center underdrain perforation spacing
S_U	ft	Underdrain transverse collector pipe spacing, center-to-center
S_{vc}	%	Average slope of vegetated channel
t_f	days	Time required for the WQv to filter through the planting soil bed
W_f	ft	Approximate filter bed width
WQv	ac-ft	Water quality volume
Z_{gravel}	in	Depth of gravel blanket

Part IIIb, Step 6) Required filter bed surface area equation derivation

$WQv = Q * t$ (Volume = Flow Rate * Time)

$Q = k * i * A$ (Darcy's Law)

$WQv = k * i * A * t$ (Substitute in Darcy parameters for Q)

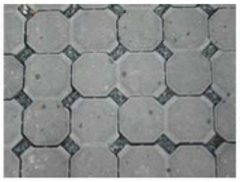
$i = \Delta h/H = (h_{avg} + d_f)/d_f$ (Darcy hydraulic gradient)

$WQv = k * [(h_{avg} + d_f)/d_f] * A_f * t_f$ (Substitute in hydraulic gradient terms)

$A_f = (WQv * d_f)/[k * t_f * (h_{avg} + d_f)]$ (Rewrite to solve for A_f)

WQv = water quality volume in (ac-ft)
d_f = planting bed soil depth in (ft)
k = coefficient of permeability for planting soil bed in (ft/day)
t_f = time required for WQv to filter through the planting soil bed in (days)
h_{avg} = average ponding depth above planting soil bed in (ft)

8.5 PERMEABLE PAVEMENT


Modular Pavers


Concrete Grids


Pervious Concrete


Porous Asphalt


Cellular Confinement Systetems

Targeted Constituents

Sediment	○
Nutrients	○
Trash	○
Metals	◐
Bacteria	◐
Oil and Grease	●
Organics	○

Legend (Removal Effectiveness)

High	Medium	Low
●	◐	○

8.5.1 Description

Permeable pavements reduce stormwater runoff and its associated pollutants by conveying stormwater through a pavement surface, providing storage, and promoting in-situ stormwater infiltration. They convey and treat stormwater runoff through a “system”, which at a minimum includes the permeable pavement and the underlying soils. This system may also include a retention/detention zone (aggregate base), a filter material (sand/filter fabric), and an underdrain or overflow system.

The structure of permeable pavements are primarily designed to function as both an outlet for stormwater runoff and a surface to transport and store vehicular traffic. Permeable pavements include but are not limited to *pervious concrete, porous asphalt, and proprietary pavement systems*.

Pervious concrete is a mixture of Portland cement, coarse aggregate, water, and admixtures. It contains little or no sand, and is sometimes referred to as “no-fines” concrete. Only enough Portland cement and water is added to the mixture to glue the aggregate together while providing void spaces for the water to percolate through.

Porous asphalt is a bituminous paving mixture of asphalt cement, coarse aggregate, and admixtures. It contains little or no sand. Only enough asphalt cement is added to the mixture to glue the aggregate together while providing void spaces for the water to percolate through.

For both pervious concrete and porous asphalt, there is a uniformly graded, clean, crushed stone aggregate base beneath the pavement. Stormwater drains through the pavement layer, is stored in the aggregate base, and infiltrates slowly into the underlying soil. A layer of non-woven geotextile filter fabric separates the stone bed from the underlying soil, which prevents the migration of fine soil particles into the aggregate base. The subsurface stone bed serves as either a storage/infiltration structure, or a simple subsurface detention basin, depending on site conditions.

Other than pervious concrete and porous asphalt, there are many different proprietary pavement systems available. For the purposes of this manual, three primary types are discussed.

- Modular Pavers – Consist of pavers that may be clay bricks, granite sets, or pre-cast concrete of various shapes. They are installed on a uniformly graded, clean, crushed stone aggregate base with permeable material placed in the gaps between the units. These impervious monolithic units convey the stormwater to the perimeter of each paver, where it is then transferred through the permeable material in the gaps to the aggregate base.

- Pre-Cast Concrete Grids – Concrete grid paving units consist of an impervious concrete grid structure that is filled with aggregate or soil, in which vegetation may be established. They are typically pre-cast at a concrete plant and shipped to the job site for placement. There are two major types of concrete grids.
  - ◊ *Lattice Pavers* – Include a flat surface that forms a continuous pattern of concrete when installed
  - ◊ *Castellated Pavers* – Include protruding concrete knobs on the surface making the grass appear continuous when installed.

Concrete grid pavers range in weight from 45 to 90 pounds and provide approximately 20 to 50 percent pervious area.

- Cellular Confinement Systems – Consists of a plastic grid that is filled with aggregate or soil. Vegetation may be planted within the cells.

8.5.2 General Application

Permeable pavement has been used across the U.S. in a variety of applications. They are primarily suitable for low-traffic areas such as driveways, parking areas, storage yards, bike paths, walkways, recreational vehicle pads, service roads, and fire lanes.

Permeable pavements are designed primarily for stormwater quality, i.e. the removal of stormwater pollutants. However, they can provide limited runoff quantity control, particularly for smaller storm events. Permeable pavements may be used in conjunction with other BMPs in order to provide a higher level of quantity control, if desired.

The permeable pavement system should be designed to receive stormwater runoff from the pavement during the water quality rainfall event as well as inflow from other impervious areas such as rooftops and driveways.

To protect groundwater from potential contamination, runoff from designated hotspot land uses or high concentrations of soluble pollutants should not be infiltrated.

8.5.3 Advantages

- Allows for reduction of standard stormwater infrastructure such as piping, catch basins, retention ponds, curbing, etc.
- May have a lower cost when considered against traditional pavement and stormwater management techniques
- Provides quantity control for small rainfall events, and reduces water into CSO systems
- Provides water quality treatment benefit
- Recharges groundwater
- Suitable for cold climate applications, maintains recharge capacity when ambient temperatures are below freezing
- Has the potential to reduce the occurrence of black ice
- Reduces the need for sand and salt use
- The life of pavement is extended due to a well drained base and reduced freeze-thaw cycles within the pavement
- Maintains traction when wet

- Reduces spray from traveling vehicles
- Reduces roadway noise

8.5.4 Disadvantages

- May cost more than traditional paving
- Can require high cost for restorative maintenance when not properly maintained
- Requires routine maintenance (annual or semi-annual depending upon site conditions)
- Proper construction stabilization and erosion control are require to prevent clogging
- Quality control for material production and installation are essential for success
- Accidental seal coating or similar surface treatment will cause failure
- Special care required for plows during snow removal, especially with pavers

8.5.5 Physical Site Suitability

8.5.5.1 Soils

The on-site soil conditions are critical to the design and performance of permeable pavement systems. A professional engineer knowledgeable in the local soils should provide soil sub-grade sampling and analysis. Soil testing should at a minimum include soil classification, moisture content, in-situ infiltration tests, and verification that the location of bedrock and the seasonal high groundwater table are not closer than three feet from the sub-grade.

8.5.5.2 Tributary Area

Where impermeable surfaces are proposed to drain onto the permeable pavement, it is recommended that the impermeable surfaces make up no more than two-thirds of the total area.

If runoff is coming from adjacent permeable areas (such as grass lots), the travel distance of the runoff should not be more than 100 feet before it is intercepted by permeable pavement and should remain sheet flow. It is important that the permeable areas be fully stabilized to reduce sediment loads and prevent clogging of the permeable pavement system. Pretreatment using filter strips or vegetated swales for removal of coarse sediments is recommended and may reduce maintenance frequency.

Sediment laden runoff from construction sites should not be allowed to drain onto permeable pavements. This is one of the leading causes of failure for infiltration BMPs.

8.5.5.3 Slopes

If the pavement sub-grade is not level, the upper portion of the pavement system will not be filled and the rainfall will quickly run to the lowest point of the system. Once the lower portion is filled, the rain will run out of the lower end of the pavement rapidly due to the high permeability of the pavement. In order to make the sub-grade level, the depth of the aggregate base should be increased on the high end of the system. Terraces or intermittent check dams may also be used to increase the storage volume on larger sites. (Hydrologic Design of Pervious Concrete, Portland Cement Association, 2007)

8.5.6 Pollutant Removal Capability

As they provide for the infiltration of stormwater runoff, permeable pavement systems have a high removal of both soluble and fine particulate pollutants, where they become trapped, absorbed or broken down in the underlying soil layers. Due to the potential for clogging, permeable pavement surfaces should not be used for the removal of sediment or other coarse particulate pollutants.

Information about the performance and removal efficiencies of permeable pavements and other BMPs can be found through the Environmental Protection Agency's Urban BMP Performance Tool website (http://cfpub.epa.gov/npdes/stormwater/urbanbmp/bmpeffectiveness.cfm).

8.5.7 Design and Construction Guidelines

8.5.7.1 Pervious Concrete

- 15-25% voids are typical for pervious concrete.
- A roller screed should be used and the concrete should be immediately covered with plastic.
- Pavement should be jointed to control cracking.
- Fibers and 6 to 7% sand should be added to the mixture to promote higher strength.
- Freeze-thaw is not an issue if the correct mix design is used.
- Contractor certification is extremely important to ensure proper installation of pervious concrete. A Certification for Pervious Concrete Contractors and Ready Mixed Concrete Producers is available through The Concrete Promotional Group and the Missouri/Kansas Chapter of the American Concrete Pavement Association. (www.concretepromotion.com)

8.5.7.2 Porous Asphalt

- 15-25% voids are typical for porous asphalt.
- A single-size crushed aggregate (1/2-inch) choker layer should be used to stabilize the surface of the aggregate base for paving.
- The National Asphalt Pavement Association (NAPA) does not have a certification process for installing porous asphalt.
- A thickened edge or ribbon curb should be installed at the interface of standard asphalt and permeable pavements.

8.5.7.3 Proprietary Pavement Systems

- Proprietary pavement systems should be selected and designed based on manufacturer's tests that show the installed unit paving system maintain a minimum of 1.1 in/hr infiltration rate over the pavement life, with a minimum initial infiltration rate of 11 in/hr. (Stormwater Source Control Design Guidelines 2005, Greater Vancouver Sewerage & Drainage District)
- It is recommended that proprietary pavement systems provide edge restraint to contain the pavers, similar to standard unit paving.
- Vegetated systems should not be used in heavily shaded areas, such as under long term parking, due to maintenance issues.
- An appropriate modular porous paver should be selected for the intended application. A minimum of 40% of the surface area should consist of open void space. If it is a load bearing surface, then the pavers should be designed to support the maximum load. (2001 Georgia Stormwater Manual, Volume 2, Chapter 3.3.8, Modular Porous Paver Systems)
- The porous paver infill is selected based upon the intended application and required infiltration rate. Masonry sand (such as ASTM C-33 concrete sand) has a high infiltration rate (8 in/hr) and should be used in applications where no vegetation is desired. A sandy loam soil has a substantially lower infiltration rate (1 in/hr), but will provide for growth of a grass ground cover. (2001 Georgia Stormwater Manual)

- A 1-inch top course (filter layer) of sand (ASTM C-33 concrete sand) underlain by filter fabric should be placed under the porous pavers and above the gravel base course. (2001 Georgia Stormwater Manual)

8.5.7.4 All Permeable Pavement Systems

- 36-42% voids are typical for the aggregate base, which is compacted at 95% proctor (use 36% voids if no data is available).
- ¾-inch clean (<2% passing #200 sieve) crushed aggregate should be used for the base.
- A minimum thickness of 12 inches should be used for the aggregate base.
- Disturbance of the sub-grade should be minimized during construction to reduce compaction and promote infiltration into the sub-soil.
- For drawdown design purposes, use 0.5 in/day of perceived infiltration/evaporation unless on-site soil permeability testing shows a higher infiltration rate.
- A non-woven geotextile fabric should be placed between the aggregate base and the subsoil to prevent the migration of fine grained soils into the aggregate base.
- Standard pavements should be used in areas of heavy truck traffic and high turning frequency due to the tendency of permeable pavements to ravel and deteriorate under high turning loads.
- Permeable pavement system designs must use some method to convey larger storm event flows to the conveyance system.
- Off-site test placements for the contractor and supplier are recommended to ensure quality, especially for first time or non-certified installers. Typically, a 10'x30' test strip is adequate.

8.5.7.5 Overflow Conveyance within the Aggregate Base:

- The aggregate base should contain an overflow conveyance system (typically perforated pipe) set at the water quality volume elevation. Volumes greater than the water quality volume will pass through the overflow conveyance and into a BMP treatment train or the storm sewer system.
- The underdrain should be designed so that the travel distance of the stormwater is no greater than 100 feet after it enters into the aggregate base.
- An inspection well may be installed in order to monitor the sub-base and the drawdown time.
- A minimum of 3 inches of cover between the perforated pipe and the bottom of the pavement should be provided. Additionally, the installation must meet the minimum cover requirements of the pipe manufacturer.

8.5.8 Maintenance and Inspections

- Cast-in-place installations can be snowplowed. Additional care is needed when plowing paving blocks or grids. Signs should be posted so that plow operators are made aware of the permeable pavement surface.
- Limit fertilizers and deicing chemicals since they will flow directly into the stormwater and groundwater.
- Salt should not be used during the first winter on concrete applications.
- Provide maintenance when the surface becomes visibly clogged or when standing water is observed on the pavement during a typical storm event.
- Semi-annual routine maintenance can be performed by a street sweeper or landscape vacuum equipment.
- Sections that have become plugged should be cleaned by a combination of pressure washing and vacuuming the liberated debris.

- Long-term maintenance is necessary to ensure proper performance.
- Inspect on a yearly basis for sediment loading.

8.5.9 Design Example

8.5.9.1 Data

A 1.5-acre overflow parking area is to be designed to provide water quality treatment for the water quality storm event (1.37 inches) using pervious concrete. Initial data shows:

- Borings show depth to water table from finished grade is 5.0 feet.
- Boring and infiltrometer tests show silty-clay with a permeability (k) of 0.018 inch/hr.
- Structural design indicates the thickness of the porous concrete must be at least 6 inches.
- A porosity of 0.36 was determined for the gravel.

8.5.9.2 Water Quality Volume (WQv)

Rv = 0.05 + 0.009 I (where I = 100 percent)

= 0.95

WQv = P * Rv * A / 12 = 1.37in * 0.95 * 1.5ac / 12in/ft

= 0.1627ac-ft = 7,087 ft^3

8.5.9.3 Thickness of Aggregate Base

The minimum depth of gravel (D_g) required below the overflow conveyance system can be calculated as:

Dg=(WQv*12in/ft)/(A*43,560ac/ft^2*n)Where,WQv = Water Quality Volume (ft^3)

A = Drainage Area (ac)

n = Porosity of Aggregate

Dg = (7,087ft^3 * 12in/ft) / (1.5ac * 43,560ac/ft^2 * 0.36) = 3.62 in

Using a 4-inch perforated pipe for the overflow system, and providing a minimum 3 inches cover between the perforated pipe and the bottom of pavement gives a total aggregate depth of 10.62 inches (use 12-inch minimum).

8.5.10 Drain Time

The minimum infiltration/evaporation rate of 0.50 inches/day (~0.0208 inches/hour) should be used since testing showed an infiltration rate of 0.018 inch/hr (0.43 inch/day).

Drawdown Time = P / k

Where

P = Water Quality Rainfall Depth (in)

k = soil permeability (in/day)

Drawdown Time = 1.37in / 0.50in/day = 2.6 days

8.6 EXTENDED DETENTION WETLAND

8.6.1 Description

Source: Applied Ecological Services

Targeted Constituents

Constituent	Removal Effectiveness
Sediment	High
Nutrients	High
Trash	Medium
Metals	High
Bacteria	High
Oil and Grease	Medium
Organics	High

Legend (Removal Effectiveness)

High ● Medium ◐ Low ○

Source: California Stormwater Quality Association, *California Stormwater Quality Association Stormwater Best Management Practice Handbook,* 2003

An extended detention wetland (EDW) is a constructed basin that has a permanent pool of water throughout the growing season and captures the water quality volume (WQv) and releases it over a 40-hour period. An EDW differs from an extended wet detention basin (EWDB) primarily in being shallower (approximately 18 inches maximum depth in an EDW main pool versus 6 to 12 feet maximum depth in a EWDB main pool). EDWs are among the most effective stormwater practices in terms of pollutant removal, and they also offer aesthetic value. As stormwater runoff flows through the wetland, pollutant removal is achieved through settling and biological uptake within the wetland. Flow through the root systems allows the vegetation to remove nutrients and dissolved pollutants from the stormwater (California Stormwater Quality Association, 2003). A temporary detention volume is provided above the permanent pool to capture the WQv and enhance sedimentation (Urban Drainage and Flood Control District, Denver, Colorado, 2005).

A distinction should be made between using a constructed wetland for stormwater management and diverting stormwater into a natural wetland. The latter practice is not recommended, and in all circumstances natural wetlands should be protected from the adverse effects of development, including impacts from increased stormwater runoff. This is especially important because natural wetlands provide stormwater and flood control benefits on a regional scale (California Stormwater Quality Association, 2003).

The EDW combines the treatment concepts of the extended dry detention basin (EDDB) and the constructed wetland. In this design, the WQv is detained above the permanent pool and released over 40 hours.

8.6.2 General Application

Because EDWs are generally shallower than EWDBs, an EDW will require a greater surface area to treat the same volume of runoff as an EWDB. For this reason, EDWs are well suited to treat runoff from large industrial and commercial project sites with ample space (City of Knoxville, 2001). When siting an EDW, it is beneficial to select a site with loamy soils for the wetland bottom to permit plants to take root and to design the normal water level to be near the wet season groundwater table. Wetland basins also require a near-zero longitudinal slope to slow the velocity of flow through them, which can be provided using embankments (Urban Drainage and Flood Control District, Denver, Colorado, 2005).

Besides pollutant removal, an EDW offers several potential advantages such as natural aesthetic qualities, wildlife habitat, erosion control, and recreational benefits such as walking paths and bird watching. It can also provide an effective follow-up treatment to onsite and source control best management practices (BMPs) that rely upon settling of larger sediment particles (Urban Drainage and Flood Control District, Denver, Colorado, 2005).

8.6.3 Advantages

- Because of the presence of the permanent wet pool with a normal residence time of at least 14 days, properly designed and maintained EDWs can provide significant water quality improvement across a relatively broad spectrum of constituents, including dissolved nutrients and many urban pollutants (California Stormwater Quality Association, 2003) (Urban Drainage and Flood Control District, Denver, Colorado, 2005).
- Widespread application of EDWs with sufficient capture volume can provide significant control of channel erosion and enlargement caused by changes to flow frequency relationships resulting from the increase of impervious cover in a watershed (California Stormwater Quality Association, 2003).
- May provide groundwater recharge – a particular advantage during periods of drought.
- Protects downstream water bodies.
- If properly designed, constructed, and maintained, EDWs can provide substantial aesthetic/recreational value and wildlife and wetlands habitat (California Stormwater Quality Association, 2003).

8.6.4 Disadvantages

- An EDW requires a relatively large footprint (California Stormwater Quality Association, 2003).
- The public can sometimes view EDWs as a safety concern when they are constructed where there is public access (California Stormwater Quality Association, 2003).
- EDW facilities may not be feasible in some locations because of insufficient tributary area to maintain the permanent pool (California Stormwater Quality Association, 2003) (Urban Drainage and Flood Control District, Denver, Colorado, 2005) (City of Knoxville, 2001).
- An EDW cannot be placed on steep unstable slopes (California Stormwater Quality Association, 2003) (Metropolitan Nashville – Davidson County, 2000).
- Overgrowth of vegetation can lead to reduced storage volume, and thus frequent monitoring is required to remove nuisance vegetation and animals (Metropolitan Nashville – Davidson County, 2000) (City of Knoxville, 2001).
- Rarely feasible in densely developed areas (Metropolitan Nashville – Davidson County, 2000).

8.6.5 Design Requirements and Considerations

The following guidelines are to be considered when designing EDWs:

- To ensure that wetland vegetation can be sustained, a water budget shall be performed for the EDW. Refer to Chapter 13 of the NRCS *Engineering Field Handbook* for techniques on calculating water budgets. (Natural Resources Conservation Service, 1997).
- Provide outlet works that limit the WQv maximum depth to 2 feet or less. If flood control volume is provided, the depth of the flood control volume can be allowed to reach a maximum of 2 feet above the WQv for up to 12 hours. See APWA 5600 for design specifications if flood control is to be incorporated into the design of the EWDB.
- The basin should be sized to hold the permanent pool as well as the required WQv. The outlet shall be designed to discharge the WQv over a period of 40 hours (California Stormwater Quality Association, 2003) (Urban Drainage and Flood Control District, Denver, Colorado, 2005). When computer software is used to

size the water quality outlet, a drawdown of 40 hours is reached when at least 90 percent of the WQv has exited the basin within 40 hours.

- The permanent pool should be configured as a two-stage facility with a sediment forebay and a main pool. The facility should be wedge-shaped, narrowest at the inlet and widest at the outlet (California Stormwater Quality Association, 2003).
- Side slopes of the basin should be 4:1 (H:V) or flatter for grass stabilized slopes. Slopes steeper than 4:1 should be stabilized with an appropriate slope stabilization practice (California Stormwater Quality Association, 2003) (Metropolitan Nashville – Davidson County, 2000).
- A sediment forebay shall be incorporated into the design to decrease velocity and sediment loading to the wetland. The sediment forebay should be separated from the wetland by an earthen berm, gabion, or loose riprap wall. The forebay shall be at least 10 percent of the WQv and shall be 4 feet to 6 feet deep. The forebay should be able to contain at least 5 years of sediment expected from the watershed. The use of a sediment forebay can extend the sediment removal interval from the permanent pool by 150 percent (Naval Facilities Engineering Service Center, 2004). The forebay consists of a separate cell formed by an acceptable barrier such as a vegetated earthen weir, gabion, or loose riprap wall (California Stormwater Quality Association, 2003). To make sediment removal easier, the bottom and side slopes of the forebay may be lined with concrete (Urban Drainage and Flood Control District, Denver, Colorado, 2005). Direct maintenance access shall be provided to the forebay.
- A separate drain pipe with a manual valve that can completely drain the wetland for maintenance purposes is recommended. To allow for possible sediment accumulation, the submerged end of the pipe shall be protected, and the drain pipe shall be sized to drain the pond within 24 hours (California Stormwater Quality Association, 2003). The valve shall be located at a point where it can be operated in a safe and convenient manner at all times. Complete gravity drawdown may be impossible for excavated wetlands, and a pump may be required to drain the permanent pool.
- Incorporate a 4-foot to 6-foot deep micropool (a capacity at least 10 percent of total WQv) before the outlet to prevent outlet clogging. A reverse slope pipe or a hooded, broad-crested weir is the recommended outlet control (Urban Drainage and Flood Control District, Denver, Colorado, 2005) (Kansas City Metropolitan Chapter of the American Public Works Administration, 2006). Locate the outlet from the micropool at least 1 foot below the normal pool surface. To prevent clogging, install trash racks, well screen, or hoods on the riser. Size the rack so as not to interfere with the hydraulic capacity of the outlet (Urban Drainage and Flood Control District, Denver, Colorado, 2005). To facilitate access for maintenance, install the riser within the embankment.
- Place aboveground berms or high marsh wedges at about 50-foot intervals and at right angles to the direction of the flow to increase the dry-weather flow path within the wetland. The flow path through the wetland should be at least 3 times the width of the facility, as measured across the center of the facility in the smallest dimension at the permanent pool elevation (Metropolitan Nashville – Davidson County, 2000).
- Surround all deep micropools with a safety bench of minimum width 12 feet, slope no steeper than 6:1, and depth of 0 to 24 inches below the pool's normal water level.
- It may be beneficial to incorporate cascades into the wetland layout, possibly by having more than one water surface elevation, or placing a cascade on one fork of a flow path and not on another. A cascade provides aeration and increases oxygen levels in the water. Oxygen is needed for the digestion of organic nutrients and particles in the water (City of Knoxville, 2001).
- Energy dissipation shall be included in the inlet design to reduce resuspension of accumulated sediment (California Stormwater Quality Association, 2003).

- Effective wetland design displays "complex microtopography." In other words, wetlands should have zones of both very shallow (<6 inches) and moderately shallow (<18 inches) depths incorporated, using underwater earth berms to create the zones. This design will provide a longer flow path through the wetland to encourage settling and plant diversity (California Stormwater Quality Association, 2003).
- The soil must be suitable for wetland vegetation. Hydric soils (soils that are normally saturated) are preferable and can be identified by wetland experts using color and texture. The soil must have an affinity for phosphorous, for which minerals containing aluminum and iron ions are typically desirable (City of Knoxville, 2001).
- One concern about the long-term performance of wetlands is associated with the vegetation density. If vegetation covers the majority of the facility, open water is confined to a few well-defined channels. This can limit mixing of the stormwater runoff with the permanent pool and reduce the effectiveness as compared to a wet pond where a majority of the area is open water. Thus, wetland vegetation should occupy between 50 and 75 percent of the surface area. Wetland vegetation should be placed along the high and low marshes of the permanent pool. The planting scheme shall be designed to result in high Manning's n values in the marshes (0.2 to 1.0) to slow the velocity of flow through the wetland and increase residence time.
- Wetland vegetation species should be selected based upon stress tolerance and hardiness to seasonal variations in water availability (City of Knoxville, 2001). Refer to suggestions and guidelines in Appendix A for vegetation selection and planting design.
- The design should include a buffer to separate the wetland from surrounding land. An average buffer width of 25 feet from the maximum WQv limit is required, with a minimum buffer width of 10 feet. Leaving trees undisturbed in the buffer zone minimizes the disruption of wildlife and reduces opportunity for nuisance vegetation to invade.
- It is beneficial to provide wildlife habitats within and around a constructed wetland.
- Standing water throughout the growing season is required to sustain wetland vegetation.
- Dams that are greater than 10 feet in height but do not fall into state or federal requirement categories shall be designed in accordance with the latest edition of SCS Technical Release No. 60, *Earth Dams and Reservoirs*, as Class C structures (Kansas City Metropolitan Chapter of the American Public Works Administration, 2006).
- A maintenance ramp and perimeter access shall be included in the design to facilitate access to the basin for maintenance activities (California Stormwater Quality Association, 2003). A 15-foot-wide access strip, with slopes less than 5:1 (H:V) shall be provided around the perimeter of the facility, unless it can be demonstrated that all points of the facility can be maintained with less access provided. The property owner shall also maintain a minimum 15-foot-wide access route to the facility from a street or parking lot (Kansas City Metropolitan Chapter of the American Public Works Administration, 2006).
- EDWs shall be designed so that runoff flows from storm events greater than the water quality event, up to and including the 1 percent event, safely pass through or around the facility. At a minimum, all facility embankments shall be protected from failure during the 1 percent event.
- Outflow structures shall be protected by trash racks, well screens, grates, stone filters, submerged inlet pipes to the outflow structure, or other approved devices to ensure that the outlet works will remain functional (Kansas City Metropolitan Chapter of the American Public Works Administration, 2006). A reverse-slope pipe can be used to prevent outlet clogging from debris. A reverse-slope pipe draws from below the permanent pool extending in a reverse angle up to the riser and establishes the water elevation of the permanent pool. Because these outlets draw water from below the level of the permanent pool, they are less likely to be clogged by floating debris (California Stormwater Quality Association, 2003) (Kansas City Metropolitan Chapter of the American Public Works Administration, 2006).

- No single outlet orifice shall be less than 4 inches in diameter (smaller orifices are more susceptible to clogging) (California Stormwater Quality Association, 2003). If the calculated orifice diameter necessary to achieve a 40-hour drawdown is less than 4 inches, a perforated riser, orifice plate, or v-notch weir shall be used instead of a single orifice outlet. Keep perforations larger than 1 inch when using orifice plates or perforated risers. Smaller orifice sizes may be used if the weir plate is placed in a riser manhole in a sump-like condition.
- All pipes through material subject to saturation within earth embankments, regardless of their designated purposes, shall be fitted with watertight cutoff collars or other accepted means of controlling seepage. Such collars shall be of sufficient size and number so as to increase the length of the seepage path along the pipe by at least 15 percent. Spacing between collars shall be 20 to 25 feet. When a single collar is to be used, it shall be placed on the pipe near the point where the centerline of the dam intersects the pipe. If two or more collars are to be installed, they shall generally be placed within the middle third of the pipe length. Generally, such collars should project a minimum of 2 feet beyond the outside of the pipe, regardless of pipe size, and should be no closer than 2 feet to a field joint (Kansas State Board of Agriculture, Division of Water Resources, 1986).
- The EDW shall be planted with wetland species suitable for design water depths. Local nurseries and the Agricultural Extension Office are good sources of information for plant species and densities. Appendix A of this manual provides information on wetland plant species.

8.6.6 Maintenance and Inspections

Routine harvesting of vegetation may increase nutrient removal and prevent the export of these constituents from dead and dying plants falling in the water. Vegetation harvesting in the summer is recommended annually (California Stormwater Quality Association, 2003).

Typical activities and frequencies include:

- Inspect the facility semiannually for burrows, sediment accumulation, structural integrity of the outlet, and litter accumulation (California Stormwater Quality Association, 2003). The banks of the EDW should be checked and areas of erosion repaired. Remove sediments if they are within 18 inches of an outlet opening (Metropolitan Nashville – Davidson County, 2000).
- Areas of erosion shall be evaluated and stabilized (Metropolitan Nashville – Davidson County, 2000) (City of Knoxville, 2001). Repair control structure as needed.
- Maintain emergent and perimeter shoreline vegetation as well as site and road access to facilitate monitoring and maintenance (California Stormwater Quality Association, 2003). Remove nuisance vegetation and animals if present (Metropolitan Nashville – Davidson County, 2000) (City of Knoxville, 2001).
- The side slopes shall conform as closely as possible to regraded or natural land contour, and shall not exceed 4:1 (H:V). Slopes showing excessive erosion may require erosion control and safety measures (Kansas City Metropolitan Chapter of the American Public Works Administration, 2006).
- Remove accumulated sediment from forebays when 50 percent of the forebay capacity is silted (Naval Facilities Engineering Service Center, 2004).
- Remove sediment from the main pool when 10 to 15 percent of the EDW permanent pool has been lost. A probing rod can be used to indicate when sediment has reached the depth corresponding to 10 percent to 15 percent of the EDW's storage volume (Metropolitan Nashville – Davidson County, 2000).

8.6.6.1 Sediment Removal

Some sediment may contain contaminants of which the Kansas Department of Health and Environment (KDHE) or Missouri Department of Natural Resources (MDNR) requires special disposal procedures. If there is any uncertainty about what the sediment contains or it is known to contain contaminants, then KDHE or MDNR should be consulted and their disposal recommendations followed. Sampling and testing shall be performed on sediments accumulated in facilities serving industrial, manufacturing or heavy commercial sites, fueling centers or automotive maintenance areas, large parking areas, or other areas where pollutants (other than "clean" soil) are suspected to accumulate and be conveyed via stormwater runoff (Metropolitan Nashville – Davidson County, 2000).

Some sediment collected may be innocuous (free of pollutants other than clean soil) and can be used as fill material, cover, or land spreading. It is important that this material not be placed in a way that will promote or allow resuspension in stormwater runoff. The sediment should not be placed within the high water level area of the EDW, other BMP, creek, waterway, buffer, runoff conveyance device, or other infrastructure. Some demolition or sanitary landfill operators will allow the sediment to be disposed at their facility for use as cover. This generally requires that the sediment be tested to ensure that it is innocuous (Metropolitan Nashville – Davidson County, 2000).

8.6.7 Design Example

The following sections present an example for designing an EDW. These procedures follow the steps outlined in the Design Procedure Form: Extended Detention Wetland Main Worksheet. When using the worksheet in electronic form, manually enter values in green.

8.6.7.1 Example

You are designing an extended detention wetland to treat stormwater runoff from a 35-acre tributary area that is developed for mixed use, including a shopping center and medium- and high-density residential areas. Size the permanent pool and WQvs of the EDW and incorporate an outlet structure that will release the WQv over a period of 40 hours.

I. Basin Water Quality Volume

Step 1 - Enter the tributary area to the EDW (A_T).

Step 2 - Calculate the WQv using the methodology presented in Section 6 of this manual.

IIa. Permanent Pool Volume, Method 1 (Florida Department of Environmental Regulation, 1988)

This method calculates the permanent pool volume required to provide a minimum detention time of 14 days to allow sufficient time for the uptake of dissolved phosphorus by algae and the settling of fine solids where the particulate phosphorus tends to be concentrated.

Step 1 - Enter the average 14-day wet season rainfall (R14). Based on the period of record for Kansas City, this is 2.2 inches.

Step 2 - Determine the Rational runoff coefficient (C) for the tributary area. This value can be obtained from APWA Section 5602.3 or estimated by delineating pervious and impervious components of the tributary area:

$$C = 0.3 + 0.6 * I;$$

I = percent impervious area divided by 100

Step 3 - Calculate the permanent pool volume (V_{P1}) from the runoff coefficient, tributary area, and average 14-day wet season rainfall:

$$V_{P1} = (C * A_T * R_{14})/12$$