Low Impact Development Manual for the Lower Maumee and Ottawa River Watersheds

American Rivers

Thriving By Nature

LOW IMPACT DEVELOPMENT MANUAL FOR THE LOWER MAUMEE AND OTTAWA RIVER WATERSHEDS

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FOREWORD

Ohio has a legacy of generating national focus on important natural resources and on policy changes. In 1969, Ohio's Lake Erie tributary, the Cuyahoga River, caught on fire shining negative attention on Ohio's water quality issues and the need for changes in water policy. Now, our region has the opportunity to become the catalyst for positive change and blaze a new trail in the Great Lakes with renewed attention on the impact of land development and redevelopment.

The Lower Maumee and Ottawa Rivers are rich water sources for our region. Our waterways are used for drinking water, fishing, recreation, tourism, and transportation, which are key components to the success of our economy. We have a responsibility to restore and protect our waterways.

There are numerous sources available for Low Impact Development (LID) techniques. This manual merges all the tools necessary to implement LID best management practices on a local level. Great attention was made to provide information that addresses local geology, hydrology, climate, and government structure. The information in this manual will arm local planners, developers, engineers, policy makers, and scientists with the tools to make decisions that will benefit our watershed.

It has been a pleasure to work with American Rivers on promoting LID in the Lower Maumee and Ottawa River Watersheds. We have worked hard to construct quality local examples and form opportunities to share experiences. I commend their efforts, and those of the Joyce Foundation, to assist our region in reducing our reliance on traditional stormwater practices and encourage natural approaches to stormwater management.

- *Patekka Bannister, Stormwater Coordinator*
  City of Toledo, Division of Environmental Services

1.0 INTRODUCTION

1.1 Purpose of the Manual

This manual is written to provide stormwater managers and site designers with a common understanding of Low Impact Development (LID) goals and objectives, site assessment considerations, and a toolbox of stormwater Best Management Practices (BMP) applicable to the Lower Maumee and Ottawa River watersheds. BMP information includes design guidelines, specifications, details, and maintenance concerns as well as assistance in selecting the BMPs based on the unique characteristics of a particular site. This is a technical manual and the information provided is targeted toward engineers, planners, landscape architects, and technical staff, as well as policy makers and developers.

In addition, this manual will help to foster a watershed approach to improving water quality within the region. With this understanding, the manual focuses on stormwater BMPs that apply across the two watersheds, ranging from using vegetated buffers in agricultural areas to vegetated roofs in urban areas. The aspiration is to create a user-friendly watershed-wide LID Manual to help protect the rivers and streams within the Lower Maumee and Ottawa River watersheds.

1.2 Watershed Description

The Lower Maumee and Ottawa River watersheds are part of the Western Lake Erie Basin in northwest Ohio and discharge to Maumee Bay in Lucas County. Refer to Figure 1-1 showing the watersheds within the basin.

In the Lower Maumee River Watershed, agriculture is the predominant land use, although activities and infrastructure typical of heavily urbanized areas are also present. Of the 2,150 miles of streams in the watershed, 41 percent are designated as impaired, including the entire main stem of the Maumee River. Agricultural practices, stream channelization, and urbanization have caused the loss of natural features which function to attenuate peak runoff, provide detention, and retain sediment. Loss of these natural processes leads to flooding, erosion, degradation of aquatic habitat, and diminished groundwater recharge.

The land area of the Ottawa River Watershed (180 square miles) is significantly smaller than the Lower Maumee (1,082 square miles) yet the populations are similar. The Ottawa River Watershed is located along the Ohio-Michigan border and drains into parts of Lucas, Fulton, Lenawee, and Monroe counties. First,

Sidebar 1-1
Watershed Statistics

Lower Maumee River Watershed
Watershed Area: 1,082 mi^2
Watershed Population: 295,700
Empties to: Maumee Bay in Lucas County
Land Use: 85% cropland, 9% woodland
Largest Cities: Toledo, Defiance, Bowling Green, and Napoleon
Counties: Fulton, Henry, Defiance, Putnam, Hancock, Wood, Lucas

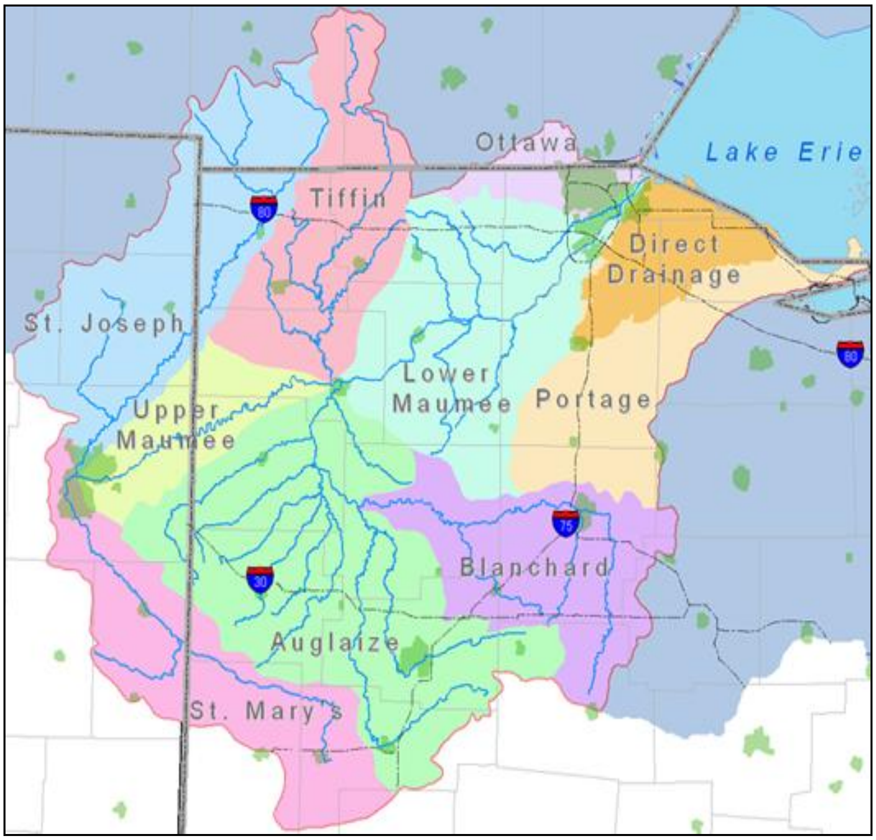
Ottawa River Watershed
Watershed Area: 180 mi^2
Watershed Population: 219,020
Empties to: Maumee Bay in Lucas County
Land Use: 16% woodland, 15% cropland, 53% "other"
Largest Cities: Toledo and Sylvania
Counties: Lucas and Fulton (Ohio); Lenawee and Monroe (Michigan)

Source:
Western Lake Erie Basin Partnership
www.wleb.org/watersheds/watersheds.html

second, and many third order reaches of the Ottawa River drain primarily agricultural regions including the following areas: the reaches west of Metamora, Ohio; the Ten Mile Creek reach north of Sylvania, Ohio extending into southern Michigan; and areas of the southwest portion of the watershed west of US 23/Interstate 475 and south of US 20. Portions of the Ottawa River east of US 23/Interstate 475 and south of the Michigan border run through heavily urbanized areas of Sylvania and Toledo, Ohio.

For more information characterizing these watersheds, refer to Chapter 3.0.

Figure 1-1 Western Lake Erie Basin Watersheds



Source: Western Lake Erie Basin Partnership

1.3 Organization and Use of the Manual

This manual is designed to provide the guidance necessary to promote the use of LID throughout the Lower Maumee and Ottawa River watersheds. It is organized into eight chapters.

Chapter 1.0: Introduction provides information on LID, identifies affected stakeholders, and provides guidance on how to use the manual.

Chapter 2.0: Regulations summarizes the federal, state, and local requirements for managing stormwater. It also encourages a more stringent goal for stormwater management based on anticipated federal rulings.

Chapter 3.0: Watershed Characteristics includes information describing the physical characteristics of the watershed including soils, topography, geology, land use, hydrology, water body impairments, and natural resources.

Chapter 4.0: Site Assessment and Planning introduces the critical elements to consider when reviewing a site for development. This chapter also discusses the principals of Better Site Design and strategies for retrofitting BMPs into existing development.

Chapter 5.0: Stormwater BMP Selection provides guidance for selecting stormwater BMPs based on site characteristics and the effectiveness of the BMP in removing target pollutants.

Chapter 6.0: Nonstructural Stormwater BMPs presents detailed information in a fact sheet format. Each fact sheet includes a BMP description, example applications, benefits and limitations, and managerial considerations.

Chapter 7.0: Structural Stormwater BMPs presents detailed information in a fact sheet format. Each fact sheet includes a BMP description, example applications, benefits and limitations, required design data, design guidelines, construction considerations, operation and maintenance issues, and design details and specifications.

Chapter 8.0: Plants for Stormwater Design recommends native plant species for the various BMPs presented in this manual. Characteristics of the plants are also identified such as sun requirements, salt tolerance, height, showiness, and soil water level requirements.

There are numerous organizations, industries, communities, professionals, and individuals who have an interest in designing and implementing LID practices within their watershed. To proactively manage stormwater and protect water quality, it will take the support of all stakeholders involved to successfully communicate, coordinate, and implement LID methods. Although the entire manual is of interest to everyone involved in this process, the chapters that may be of the most use to a given stakeholder are identified in Table 1-1.

Table 1-1 Use of Manual by Stakeholder

Stakeholder	Role in LID	Primary Interests	Key Chapters
Local Officials	• Set policy • Develop/Update ordinances	• LID basics • Potential for cost savings • Achievable performance measures	1, 2, 3
Planning Commission	• Review development proposals • Develop master plans • Develop/Update ordinances	• LID basics • Incorporate LID into master plans	1, 2, 3, 4

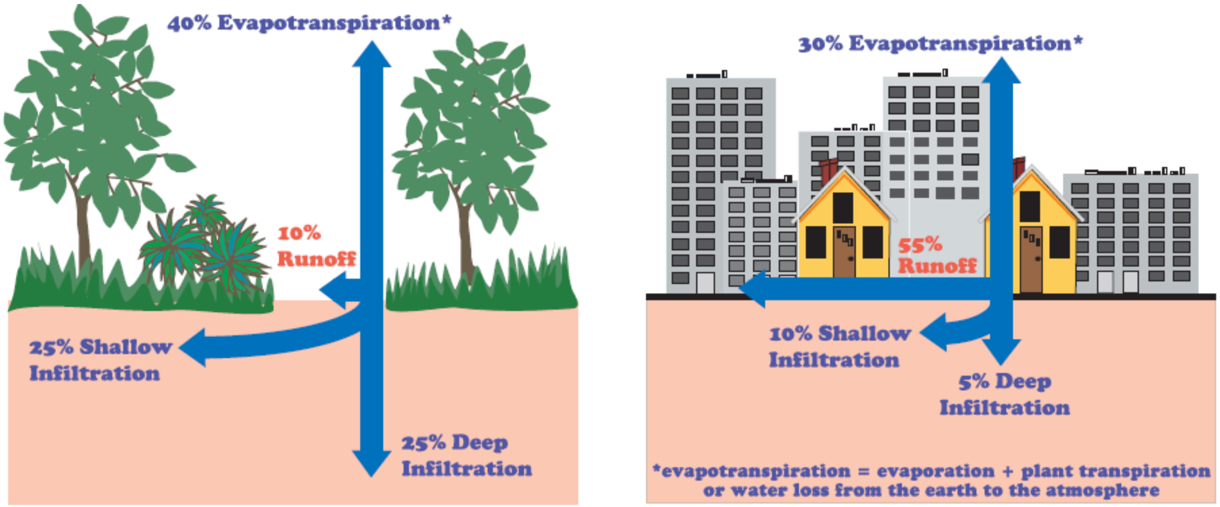
Stakeholder	Role in LID	Primary Interests	Key Chapters
Staff Planners/ Planning Consultants	• Review development proposals • Review site plans • Educate community about LID	• LID basics • Incorporate LID into site plans • LID design guidance	1, 2, 3, 4, 5, 6, 7, 8
Engineers/ Developers/ Landscape Architects	• Design site development • Review site plans • Advise planning commissions	• Incorporate LID into site plans • LID design guidance	4, 5, 6, 7, 8
Public Works/ Road Commission/ Ohio Department of Transportation	• Design roads and drains • Implement BMPs • Maintain BMPs	• Incorporate LID into site plans • LID design guidance • LID maintenance requirements	5, 6, 7, 8
Citizens/ Businesses/ Environmental Groups	• Implement BMPs on private property • Maintain BMPs • Promote LID	• LID basics • Incorporate LID into site plans • LID design guidance • LID maintenance requirements	1, 2, 3, 4, 5, 6, 7, 8

1.4 Impacts of Development

1.4.1 Hydrologic Impacts

Transitioning from a native landscape to a built environment increases the impervious surface coverage including roads, parking areas, sidewalks, and rooftops. These alterations reduce, disrupt, or entirely eliminate native vegetation, upper soil layers, shallow depressions, and native drainage patterns that intercept, evaporate, store, slowly convey, and infiltrate stormwater. See Figure 1-2. As development progresses, the portion of small watersheds contributing overland flow to receiving waters in minutes increases, while the portion that stores stormwater and delivers subsurface flow over periods of hours, days, or weeks diminishes (Booth et al., 2002). This change in hydrologic regime can significantly degrade stream habitat (Booth, 1991). Recent studies suggest that a subwatershed with as little as 5 to 10 percent impervious cover can negatively impact the quality of the receiving stream (Schuler et al., 2009).

Figure 1-2 Hydrologic Regime: Green Landscape versus Urban Landscape



1.4.2 Water Quality Impacts

In addition to impacts on stream health caused by hydrologic regime change, impacts are also attributed to stormwater pollution. Impervious cover harbors pollutants from a variety of sources in the urban environment including the atmosphere, lawns, gas stations, parking lots, and streets. Numerous studies have shown that stormwater runoff typically contains the following pollutants (Schueler and Holland, 2000):

- Sediment from eroded stream banks and construction sites;
- Nutrients and pesticides from fertilizer and grass clippings left on pavement;
- Organic carbon from litter;
- Trace metals (copper, zinc, and lead) and petroleum hydrocarbons from vehicles;
- Fecal coliform bacteria from pet and wildlife waste; and
- Chlorides from road salt in cold climates (SEMCOG, 2008).

During storms, pollutants are washed off surfaces and are rapidly discharged to water bodies. A summary of stream response to changes in the condition of the watershed are shown in Table 1-2. Overall, these changes diminish recreational and economical opportunities for communities within the watershed.

Table 1-2 Degradation of Watershed Conditions and Stream Response

Change in Watershed Condition	Response
Increased drainage density due to road networks, road crossings, and stormwater outfalls	• Increased storm flow volume and rate • Increased flooding and property damage • Increased channel erosion • Increased fine sediment and urban water pollutant loads • Increased fish passage barriers • Decreased groundwater recharge • Decreased dry weather flow in streams • Increased temperature of runoff and streams
Increased fine sediment deposition	• Reduced dissolved oxygen levels in streambed • Loss of fish and macroinvertebrate habitat
Loss or fragmentation of riparian areas	• Reduced delivery of large woody debris • Reduced bank stability and loss of bank habitat structure and complexity • Reduced shading and temperature control
Reduced quantity and quality of large woody debris	• Reduced channel stability, sediment storage, instream cover for fish and insects, and loss of pool quality and quantity
Increased pollutant loads	• Synthetic organic compounds and trace elements: some acutely toxic; tumors in fish; salmon and trout will alter spawning and migration behavior in presence of metals as low as <1% of lethal concentration; endocrine disruptors • Nutrients: excessive aquatic plant growth; excessive diurnal oxygen fluctuations • Synergistic influence of multiple pollutants unknown
Loss of natural streams due to ditching	• Permanently removes any ecological benefits they may have • Increased downstream flooding due to a reduced cross-sectional area and reduced channel roughness

Source: Hinman, 2005

1.5 Low Impact Development Goals and Objectives

In response to the detrimental impact of impervious cover on receiving water bodies, LID has evolved to become a widespread stormwater management and land development strategy. LID is applied at the parcel and subdivision scale and emphasizes conservation and use of on-site natural features integrated with engineered, small-scale hydrologic controls to more closely mimic predevelopment hydrology. Predevelopment hydrology is described as the hydrology of an area over the full range of rainfall intensities and durations for a predevelopment forested or prairie condition based on historical records describing that site.

1.5.1 Low Impact Development Goal

The primary goal of LID is to prevent harm to streams, lakes, wetlands, and other natural aquatic systems from commercial, residential, or industrial development sites. To accomplish this, LID practices promote infiltration, evapotranspiration, and capture and reuse of stormwater runoff close to its source. Practices range from preserving and restoring natural features to incorporating rain gardens, green roofs, and other structural BMPs into new site development and redevelopment projects. These LID practices can be used alone, in concert with one another, or in combination with traditional stormwater practices depending on the stormwater management criteria and the characteristics of the site.

1.5.2 Traditional Stormwater Management Goal

In contrast to LID, traditional stormwater management practices focus on efficient collection and rapid conveyance of stormwater away from development to large flood control basins sized to handle large flood events. While this approach can often mitigate to predevelopment peak flows, it is usually not effective in removing the volume of stormwater discharge which results in unnaturally prolonged elevated flows to drain the basin within an acceptable time period. These elevated flows often exacerbate stream bank erosion and contribute to aquatic habitat loss. In addition, concentrated discharges at outfalls cause localized stream damage.

Despite the fundamental differences between LID and traditional stormwater management, a combination of the practices used in these two strategies may be the best approach in meeting stormwater management quality and quantity criteria for a given site.

1.5.3 Low Impact Development Objectives

To mimic the predevelopment hydrology of a site, LID uses the following objectives:

- Minimize total runoff volume;
- Control peak rate of runoff;
- Maximize infiltration and groundwater recharge;
- Maintain stream base flow;
- Maximize evapotranspiration; and
- Protect water quality.

Many of these objectives can be met by <u>minimizing</u> 1) soil compaction, 2) impervious surfaces, 3) direct connection of impervious surfaces, and 4) greenfield disturbance.

1.5.4 Benefits of Implementing LID

The benefits of implementing LID practices can be categorized into environmental benefits, land value benefits, and compliance incentives as studied by the U.S.EPA (U.S.EPA, 2007). The following list describes the benefits largely accepted by the industry. Note that studies quantifying the economic benefit of implementing LID are recently emerging and are much more difficult to discern than studies quantifying traditional stormwater management practices.

Environmental Benefits

- Reduce runoff volume and thus pollutant loadings to receiving streams
- Reduce stream channel degradation from erosion and sedimentation
- Improve water quality
- Enhance the recreational and aesthetic value of the natural resource
- Reduce incidence of illness from swimming and wading
- Improve natural fishery health
- Increase groundwater recharge
- Increase stream baseflow
- Reduce need for stormwater retention facilities
- Reduce water supply treatment costs
- Reduce incidence of combined sewer overflows
- Improve wildlife habitat
- Decrease stream mitigation and restoration costs

Sidebar 1-2
Green Values®
Stormwater Toolbox

For more information on the cost of "green" stormwater BMPs versus the cost of traditional stormwater systems, go to: **http://greenvalues.cnt.org/**

This Center for Neighborhood Technology website hosts several on-line stormwater management calculators, which are available to use free of charge.

Land Value Benefits

- Reduced downstream flooding and property damage
- Real estate value/property tax revenue
- Lot yield
- Aesthetic value
- Public spaces/quality of life/public participation

Compliance Incentives

- Regulatory compliance incentives

Cost Considerations

The following should be considered when comparing costs between traditional stormwater management approaches and LID-based approaches. This information, as well as detailed case studies, is found in *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices* (USEPA, 2007).

Reduced Material Costs

Traditional approaches to stormwater management involve conveying runoff to receiving waters, to a combined sewer system, or to a regional facility that treats runoff from multiple sites. These designs typically include hard infrastructure, such as curbs, gutters, and piping. In contrast, LID-based designs are designed to use natural drainage features or engineered swales and vegetated contours for runoff conveyance and treatment.

LID techniques, such as conservation design, can reduce the total impervious surface, which results in reduced materials needed for roads, driveway lengths, curbs, and gutters. Reduced material translates to reduced costs. Other LID techniques, such as grassed swales, can be used to infiltrate roadway runoff and eliminate or reduce the need for curbs, gutters, and sewers. By infiltrating or evaporating runoff, LID techniques can reduce the size and cost of flood-control structures. Note that more research is needed to determine the optimal combination of LID techniques and detention practices for flood control.

Be aware that the use of LID techniques might not always result in lower project costs. The costs might be higher because of the costs of plant material, site preparation, soil amendments, underdrains and connections to municipal stormwater systems, and increased project management.

Reduced Land Cost

Another factor to consider when comparing costs between traditional and LID designs is the amount of land required to implement a management practice. Land must be set aside for both traditional stormwater management practices and LID practices, but the former require the use of land in addition to individual lots and other community areas, whereas bioretention areas and swales can be incorporated into the landscaping of yards, in rights-of-way along roadsides, and in or adjacent to parking lots. The land that would have been set aside for ponds or wetlands can in many cases be used for additional housing units.

Reduced Maintenance Costs

Maintenance requirements should also be considered. Although a 1999 EPA report estimated that maintenance costs for retention basins and constructed wetlands were 3 to 6 percent of construction costs, and maintenance costs of swales and bioretention were 5 to 7 percent of construction costs, there are opportunities to save costs with LID by soliciting volunteers. Much of the requirements for sustaining LID practices involve routine landscape maintenance which homeowners, neighborhood associations, or environmental groups can accomplish. Maintenance of ponds and basins often require heavy equipment to remove accumulated sediment, oils, trash, and unwanted vegetation.

Avoid Stormwater Fees

Municipalities sometimes charge fees when stormwater mitigation requirements are not met, and if they do not now, they may in the future. In urban redevelopment projects where land is not likely to be available for stormwater control, developers can incorporate site-dispersed LID practices in sidewalks, courtyards, rooftops, parking lots, and other small outdoor spaces, thereby meeting the requirements and avoiding fees.

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2.0 REGULATIONS

Stormwater management is regulated in the Lower Maumee and Ottawa River watersheds by federal, state, and local rules and addresses both water quantity and water quality. Water quantity rules, often referred to as flood management, have historically been part of traditional stormwater management practices and are familiar to many, but water quality rules are relatively new. It is expected that the present stormwater management regulations will continue to evolve as stormwater managers learn more about efficient mitigation methods and the effects of development on stormwater runoff and our environment.

Federal regulations were developed for stormwater management and permitting in the early 1990s and expanded over the past two decades to address construction activity, industrial sites, and municipal stormwater systems. In Ohio and Michigan, the enforcement of these regulations is delegated to the state. Local governmental agencies are both regulated as permittees and regulators of stormwater management in the watersheds. The following summary describes the applicable regulations and how they might affect the use of LID methods.

2.1 Construction Regulations

Sites that are being developed or redeveloped are subject to the Ohio Environmental Protection Agency (OEPA) stormwater permitting rules or the Michigan Department of Natural Resources and Environment (MDNRE) soil erosion and sedimentation control rules.

Federal and State Regulations

Ohio

The Ohio rules (Ohio EPA Permit No. OHC000003) require the site owner or developer to file for permit coverage before construction begins. The permit application is a Notice of Intent (NOI) that describes the proposed development. The developer must also prepare a Stormwater Pollution Prevention Plan (SWP3) that includes BMPs for:

- Sediment and erosion control;
- Controls for pollutants other than sediments; and
- Post construction stormwater management.

OEPA may ask to see the SWP3 during an inspection or ask that it be submitted to the Agency. Note that the SWP3 should only be submitted to OEPA if requested. Refer to Table 2-1 for a summary of the documentation that is required to be included in the SWP3. Engineers and SWP3 designers have the flexibility to present this information in a wide variety of formats. However, the SWP3 should contain all the information necessary for contractors to fully implement the practices in a timely way. When designing a SWP3, it is important to produce a document that incorporates effective stormwater strategy with the site development.

Table 2-1 SWP3 Documentation

Narrative Information
Copy of permit requirements
Cover page or title identifying the name and location of the site, the name and contact information of all construction site operators, the person responsible for authorizing and amending the SWP3, the preparation date, and the estimated dates that construction will start and be complete
Description of the nature and type of construction activity that will occur
Total site area (acres) and site area expected to undergo construction activities (acres)
Runoff coefficients for the pre-construction and post construction condition of the site
The impervious area (acres) created as a result of development, including impervious areas created by others within the development
The percent of imperviousness created as a result of development
Describe prior land uses, including special considerations to be addressed as a result of those prior land uses. Include any existing data describing soils or quality of stormwater discharges
Implementation schedule, which coordinates major construction operations with the implementation of erosion, sediment, and stormwater management controls or operations
A log documenting grading and stabilization activities as well as amendments to the SWP3, which occur after construction activities commence
Name and location of immediate receiving stream(s) or surface water(s) and the subsequent named receiving water(s)
Describe post construction stormwater practices
Inspection reports as required by the NPDES permit (see Maintenance Requirements)
Pictorial Information
Site vicinity map
Limits of earth-disturbing activity, including areas used for borrow or spoil
Soil types for all areas of the site, including locations of unstable or highly erodible soils and depth to bedrock
Existing/Proposed contours, including a delineation of drainage watersheds expected during and after major grading activities as well as the size of each drainage watershed (acres)
Location of surface waters on or within 200 feet of the site, including springs, wetlands, streams, lakes, etc.
Existing and planned locations of buildings, roads, parking facilities, and utilities
Location of erosion control measures (e.g., seeding, matting, rip rap, and mulching) and areas likely to require temporary stabilization during the course of site development
Location of sediment ponds, including stormwater management ponds used for the purpose of sediment control. Note the storage volumes (yd^3) and drainage areas (ac)
Location of post construction stormwater practices
Areas designated for storage or disposal of solid, sanitary, and toxic wastes, including dumpster areas, areas designated for cement truck washout, and vehicle fueling

Narrative Information
Location of designated construction entrances where vehicles will access the site
Location of any in-stream activities, including stream crossings
Detail drawings and specifications for all sediment and erosion controls and post construction stormwater management practices

Michigan

Michigan has two statutes/rules (known as Part 31 and Part 91 of Act 451) which are used to regulate Soil Erosion and Sedimentation Control (SESC) on construction projects that disturb one or more acres. Together these rules require the following:

- Develop and implement an SESC Plan and include any post construction BMPs.
- Submit a permit application. Refer to Sidebar 2-1 for guidance.
- Comply with the permit, including maintaining BMPs, inspecting the site, and stabilizing the site at the end of construction activity.

Sidebar 2-1
Michigan SESC Permit Guidance

Construction activity disturbing...
One or more acres or within 500 feet of a water body must obtain a "Part 91" permit from the permitting agency.

Five or more acres must additionally submit a Notice of Coverage (NOC) application, a location map, and a fee to the MDNRE. Authorization must be received before construction begins.

If you think you need a permit, the best thing to do is contact the local Soil Erosion Permitting Agency for details on the permitting process. Visit the MDNRE SESC Home Page at www.michigan.gov/deq then "Land" for a list of SESC permitting agencies by county.

Federal

On December 1, 2009, the U.S. Environmental Protection Agency (USEPA) finalized new standards to control construction site erosion and sediment discharges. The new rule contains monitoring requirements with a numeric limit on the sediment content (measured as turbidity) in stormwater discharges that will take effect in August of 2011. The rule requires a range of erosion and sediment control BMPs, including LID practices such as minimizing disturbed areas and impervious areas. There are also more stringent requirements for soil stabilization. These rules will be phased in, first applying to sites 20 acres and larger, then to sites that disturb ten or more acres. The federal rules must be adopted by the state, including OEPA and MDNRE, and thus will apply to the Lower Maumee and Ottawa River watersheds. More information on the new rules is available at **www.epa.gov/guide/construction/**.

Local Regulations

Local regulations including those from a village, township, city, or county may be more stringent than the state rule and submittal requirements may vary from jurisdiction to jurisdiction. The developer, stormwater engineer, or site designer should verify regulations and submittal requirements with the local jurisdiction of the proposed development site.

Other Considerations

Other federal, state, or local rules regarding construction, wetlands, floodplains, endangered species, or historical preservation could apply. Designers should verify and follow applicable procedures of local or county zoning and building inspection departments, the local Soil and Water Conservation District, the local planning commission office, the county Drain Commissioner's Office (Michigan only) or the local County/Municipal Engineer's office.

LID practices should be incorporated early in the design process, particularly nonstructural controls such as phasing construction activities, minimizing soil compaction, and minimizing impervious area. Some structural controls can be used in the construction phase as well as during the site's occupancy and use (post construction phase), but generally there will be modifications needed to accommodate the differences in runoff volumes, sediment load, and maintenance requirements. These practices should be integrated into the development design documents and included in the SWP3 (Ohio) or SESC Plan (Michigan). More details are provided in Chapters 4.0 and 5.0 on incorporating LID into the site design and how each practice can be applied.

2.2 Post Construction Control Regulations

Ohio

The Post Construction Stormwater Management requirements are included as a subsection under the Stormwater Pollution Prevention Plan (SWP3), Part III of the Ohio EPA Permit No.: OHC000003, "Authorization for Stormwater Discharges Associated with Construction Activity under the National Pollution Discharge Elimination System."

The purpose of the Post Construction Stormwater Management requirements is to ensure protection of the receiving stream's physical, chemical, and biological characteristics and to ensure the stream's functions are maintained.

Related to post construction, the SWP3 must include the following:

- A description of post construction BMPs that will be implemented for a construction site;
- The basis for their selection addressing the projected impacts on the channel, floodplain morphology, hydrology, and water quality; and
- Detail drawings and maintenance plans that ensure pollutants collected from the BMP practice are disposed of in accordance with local, state, and federal regulations.

Operation and maintenance of post construction practices are required through the valid expiration date of the Permit by the permittee (except for those regulated under the small Municipal Separate Storm Sewer Systems, or MS4, program), which is followed by the on-going operation and maintenance by the post construction operator. The permittee is required to provide a maintenance plan to the post construction operator.

Construction projects that are linear in nature and do not result in a net increase in impervious surface, such as road resurfacing projects, are excluded from the requirements listed in Part

III.G.2 of the Permit, provided the project is designed to minimize stream crossings and disturbance.

Requirements for Large Construction Activities

Large construction includes activities involving a disturbance of five acres or more of land or involving a disturbance of less than five acres, but is part of a larger plan of development which totals more than five acres of land.

Post construction BMPs for large construction activities:

- BMPs must demonstrate the ability to detain stormwater runoff to protect stream channels, prevent stream erosion control, and improve water quality.
- The BMP must be sized to treat the Water Quality volume (WQv) and must be in compliance with Ohio's Water Quality Standards in OAC Chapter 3745-1.
- The WQv shall be equivalent to the volume of runoff from a 0.75-inch rainfall (for approved computation methods see Part III.G.2.e of the Permit).
- The BMP shall incorporate an additional volume equal to 20 percent of the WQv to allow for sediment storage and/or reduced infiltration capacity.
- BMPs should be designed according to the methodology included in the Rainwater and Land Development manual or a manual accepted for OEPA use.
- BMPs shall be designed such that the draw down time is long enough to provide treatment, but short enough (average of 24 to 48 hours) to provide storage available for consecutive rainfall events (refer to Table 2 of Part III.G.2.e of the Permit for specific BMP draw down times).

Any redevelopment project shall implement BMPs such that a 20 percent net reduction of impervious area is achieved, such that at least 20 percent of the WQv is treated, or provide a combination of the two.

Requirements for Small Construction Activities

Small construction includes activities involving a disturbance of one acre or more but less than five acres of land and is not included in a larger plan of development totaling more than five acres of land.

The SWP3 must include a description of measures to be implemented to control pollutants from the site after construction is completed. Structural measures (including velocity dissipation devices) shall be placed on uplands to the "degree attainable." Refer to *"Small Construction Activities"* in Part III.G.2.e of the Permit for specific practices.

Michigan

Post construction stormwater control requirements for new development and redevelopment projects in Michigan are specified in the NPDES permit for stormwater discharges from a

Municipal Separate Storm Sewer System (MS4), Part I.A.4. This applies to MS4 owners or operators that are located in a 2000 Census Urbanized Area and only for projects that disturb one acre or more. Within the Lower Maumee and Ottawa River watersheds, this only applies to a small portion of the Ottawa River Watershed as shown in Figure 2-1. In summary, Michigan requires the following:

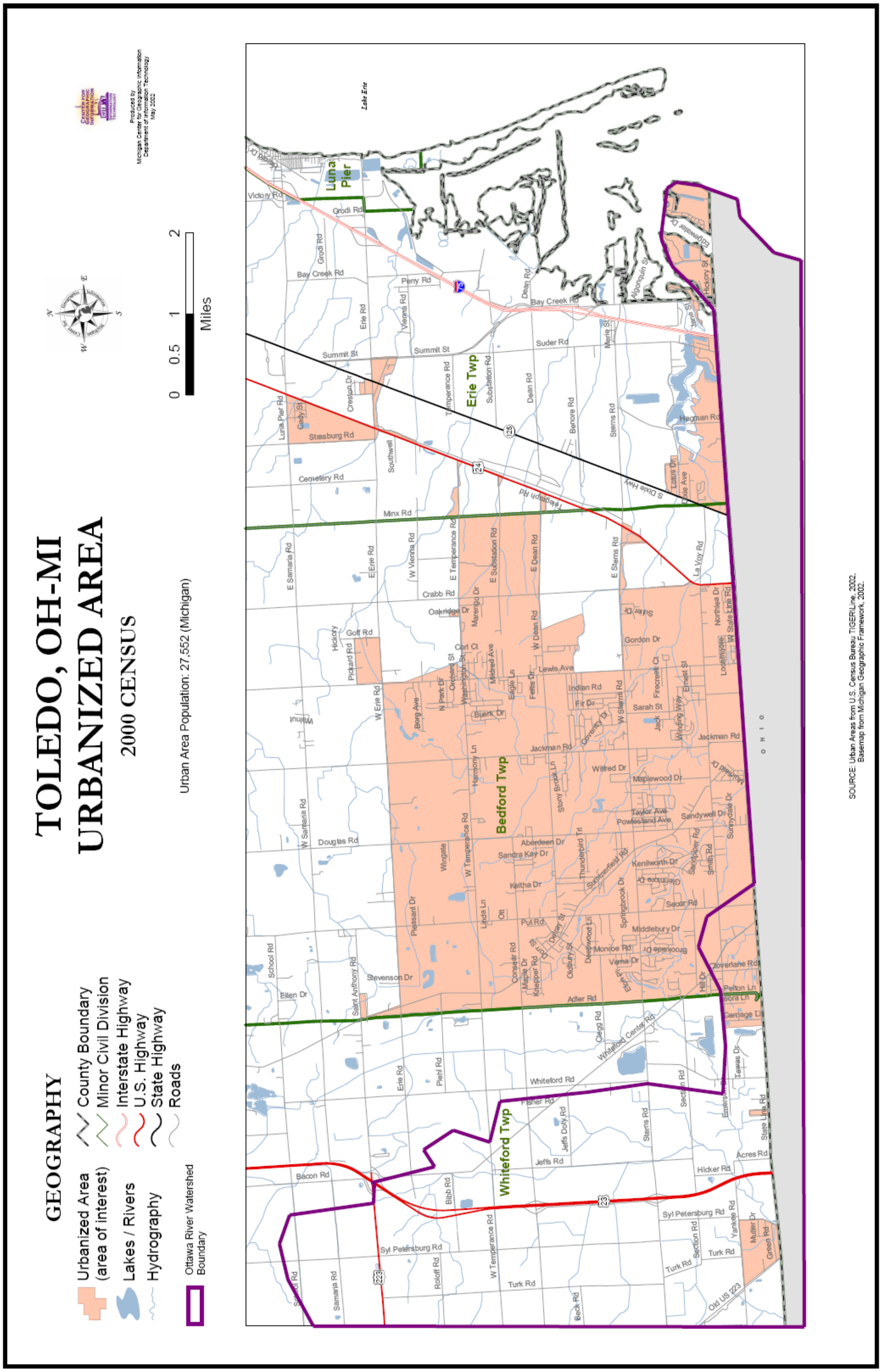
- A *minimum treatment volume standard* of 1 inch of runoff from the entire site or runoff from the 90 percent annual non-exceedence storm for the region. A minimum of 80 percent removal of total suspended solids (TSS) is required or a discharge concentration not to exceed 80 mg/L of TSS.
- The *channel protection criteria* requires maintaining post-development site runoff volume and peak flow rate at or below existing levels for all storm events up to the two-year, 24-hour event.
- All structural BMPs shall include a plan for long-term operation and maintenance (O&M). The permittee shall develop, track, and enforce a program to ensure long-term O&M.

For more detail concerning the requirements, go to **www.michigan.gov/deq**; click on “water,” “surface water,” and then “stormwater.” Approved local standards may differ from the above, so the developer or engineer should check local requirements.

Local Regulations

Local regulations may be more stringent than the state rules. The developer, stormwater engineer, or site designer should verify requirements with the local jurisdiction of the proposed development site.

Figure 2-1 Toledo, Ohio - Michigan Urbanized Area



2.3 Future Directions

The practice of stormwater management has been evolving over the past few years to focus more on water quality protection. Federal agencies have promoted LID and are proposing more regulation; state agencies have begun to require more quantitative performance standards; and some local stormwater authorities are requiring even more extensive use of LID because of its benefits. Some examples are cited below to provide a preview of the possible coming changes to stormwater management practice.

The USEPA guidance document, *Managing Stormwater in Your Community: A Guide for Building an Effective Post Construction Program, July 2008*, recommends that stormwater management agencies develop criteria for runoff controls based on rainfall distribution plots or Rainfall Frequency Spectrum curves. These are plots of rainfall data that will estimate the frequency of a given size rainfall event. The guidance recommends that the 90th percentile rain event should be used for the volume of runoff to be controlled on-site using runoff reduction and water quality volume treatment. For channel protection, the 99th percentile amount or one-year storm is the recommended criterion for control. In Toledo, these rainfall amounts are 0.90 inches (90th percentile) and 2.03 inches (99th percentile). Refer to Sidebar 2-2 for more information on how this was calculated.

Sidebar 2-2 Toledo Rainfall Frequency Spectrum[a]

% of All Storm Events[b]	Rainfall Depth, inches
99	2.03
95	1.23
90	0.90
85	0.75
70	0.46
50	0.28
30	0.19
10	0.12

a. *1955 to 2009 hourly rainfall record at Toledo Express Airport (NOAA gauge), excluding all storms less than 0.10 inches that were separated by three consecutive hours from the next storm.Calculation follows the guidance, "Design of Stormwater Filtering Systems," (Claytor, 1996).*

b. *Equal to or less than the given rainfall depth.*

Section 438 of the Energy Independence and Security Act of 2007 contained a requirement that federal facility development and redevelopment projects "… shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the **temperature**, **rate**, **volume**, and **duration** of flow." In December 2009, a technical guidance document was issued by USEPA that specifies a performance design objective of retaining the 95th percentile rainfall event. Although this law applies only to federal building projects, it indicates strong support for LID practices at the federal level and is likely to become a standard used by other regulatory agencies.

In late 2009, USEPA issued a notice that the agency plans to develop new rules to strengthen stormwater regulations on newly developed and redeveloped sites (**http://cfpub.epa.gov/npdes/stormwater/rulemaking.cfm**). The notice did not provide technical details of these rules, but included surveys that indicate that a broad range of techniques, including LID, are being considered. From this announcement and USEPA's past support for LID, one could reasonably assume that the future stormwater regulations will include LID elements.

In 2009, West Virginia modified the General WV/NPDES Permit for Small Municipal Separate Storm Sewer Systems (MS4s) to include stormwater management system performance standards for new development and redeveloped sites. The standards are based on the limit of 10 percent of runoff allowed to flow off the site. A rainfall distribution analysis of West Virginia climate data (as described in USEPA guidance) determined that the 90th percentile 24-hour rainfall depth is 1.0 inch, so the standard specifies that runoff reduction practices will "… infiltrate, evapotranspirate and/or capture and use the first inch of rain from a 24-hour storm preceded by 48 hours of no measurable precipitation." There are incentives in the permit that reduce this standard for redevelopment projects, brownfield redevelopment, high density development, vertical density developments, and mixed use and transit-oriented development.

In the Big Darby Creek Watershed, near Columbus, Ohio, where there is a high-quality stream and significant development pressure, the stormwater permit includes post construction infiltration requirements. The groundwater recharge after construction is completed must be equal to or exceed the preconstruction groundwater recharge. The permit specifies that the SWP3 must describe the conservation development strategies, stormwater control measures, and other practices that will be used to maintain or improve predevelopment rates of groundwater recharge.

There are 11 Minimum Stormwater Management Standards in the Georgia Stormwater Management Manual. These include use of Better Site Design and other LID practices. The standard for runoff quality has a water quality volume defined as the runoff from 1.2 inches of rainfall.

The North Carolina Permit To Construct, Operate and Maintain Impervious Areas and BMPs Associated with Residential Development Disturbing Less Than 1 Acre specifies that stormwater runoff shall be managed using: rain cisterns, rain barrels, or rain gardens; use of permeable pavement; or other BMPs that will control and treat the stormwater runoff from all built-upon areas of the site from the first 1.5 inches of rain.

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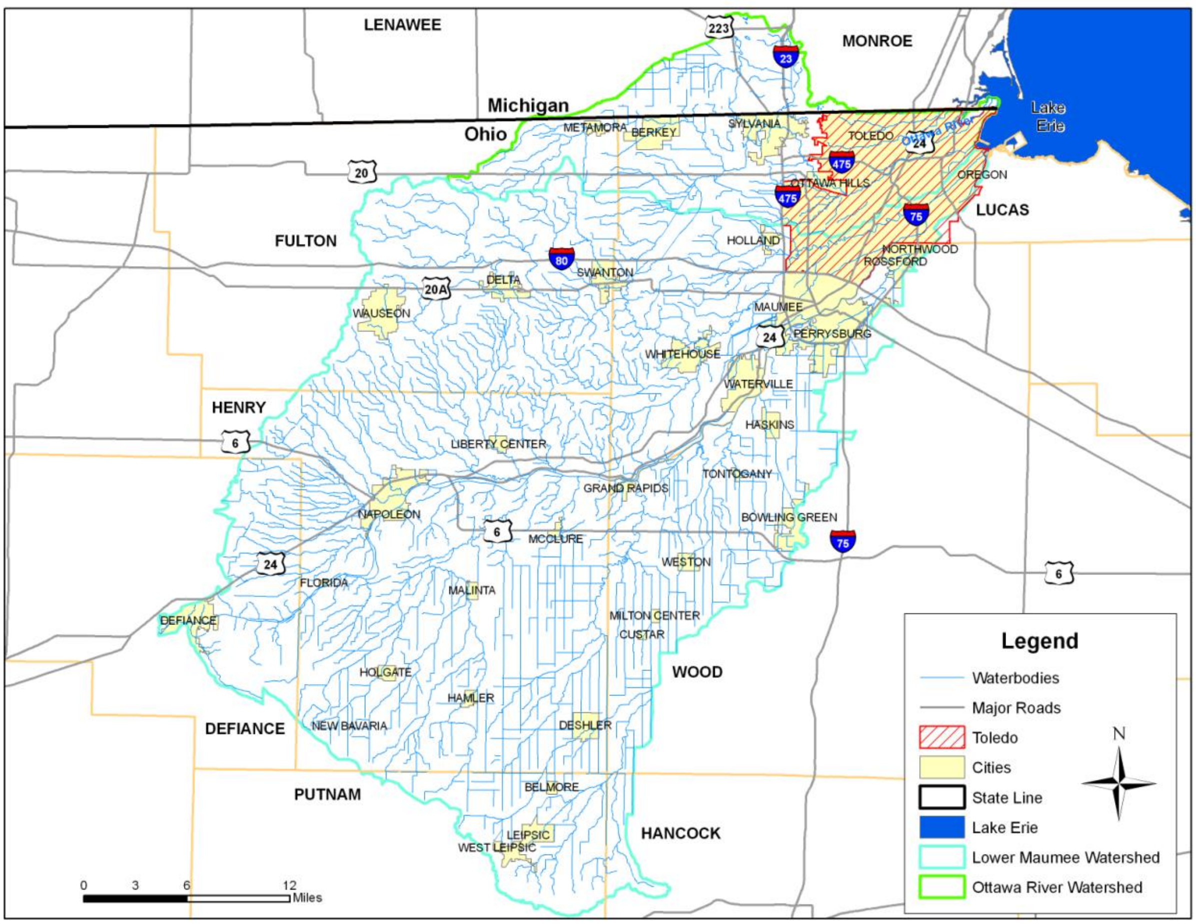
3.0 WATERSHED CHARACTERISTICS

The Lower Maumee and Ottawa River Watersheds lie in the western Lake Erie basin and encompass portions of nine counties in northwest Ohio and southeast Michigan. The combined area of the two watersheds is 1,262 square miles with a total population of slightly more than 500,000. Agriculture is the primary land use activity, although portions of each watershed contain residential areas as well as highly urbanized areas (NRCS-USDA, 2005).

This chapter provides a summary of some of the prominent characteristics of the watershed including land use, soil and geology, topography, weather, population, water bodies, and impaired water bodies. Planners should reference this chapter and other local planning tools early in the planning stages of a project to gain an overview of an area and insight as to which LID practices may be appropriate. Refer to Chapter 5.0, Stormwater BMP Selection, to see which LID practices are favorable in particular areas. Figure 3-1 shows general information about the watershed.

Figure 3-1 Ottawa River and Lower Maumee Watershed Map

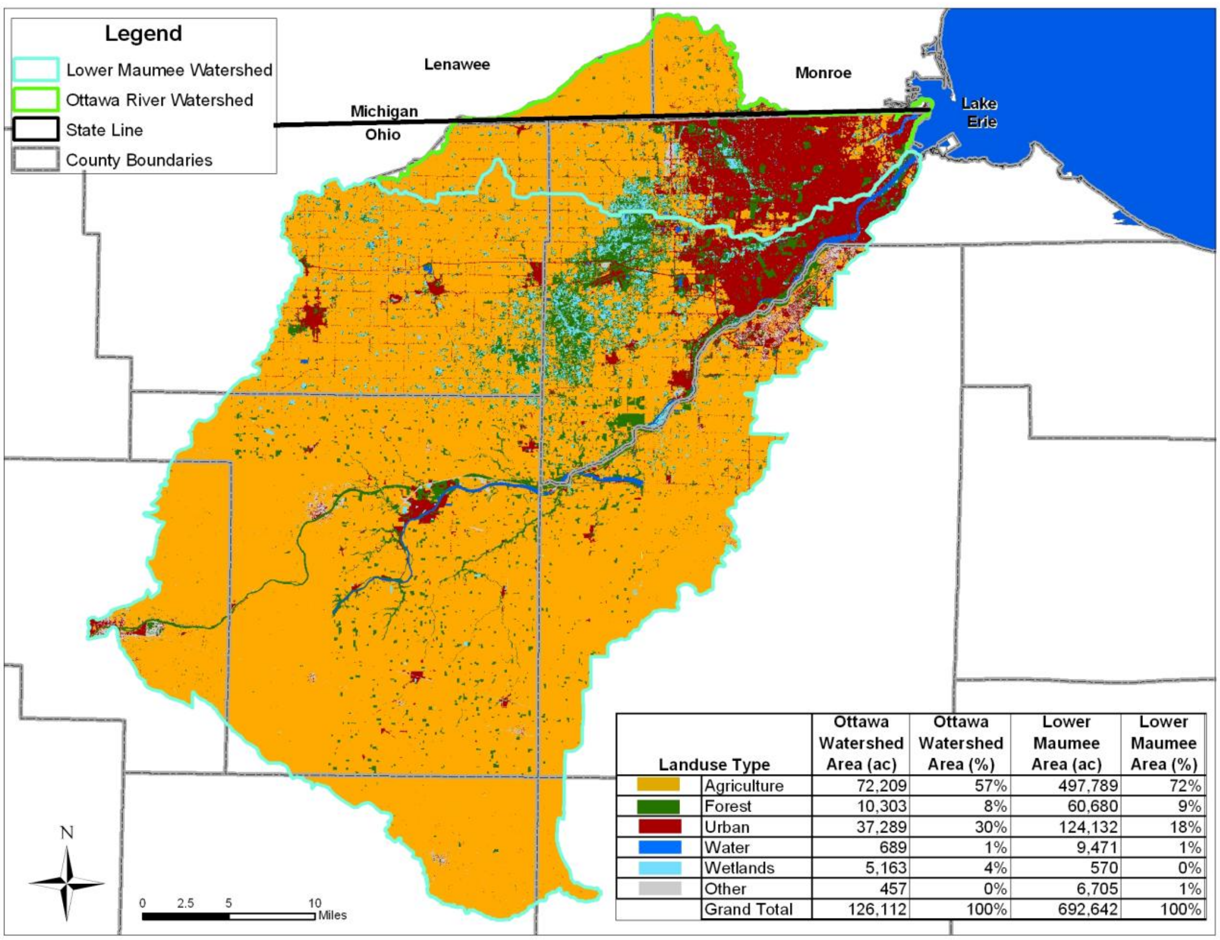


Land Use

A 1997 survey by the National Resource Inventory found that the Lower Maumee Watershed is predominately agricultural (>70 percent) with an additional 9 percent woodland. Urban areas accounted for 18 percent of land use and 1 percent was covered with water with less than 1 percent of the land under the Conservation Reserve Program (NRCS, 2009).

Agriculture plays an equally important role in the Ottawa River Watershed (57 percent) with 8 percent of the landscape consisting of forest. With the inclusion of the City of Monroe, Michigan, 30 percent of the watershed is an urban mixture of neighborhood, industrial, and commercial uses (NRCS-USDA, 2005). Refer to Figure 3-2 showing the land use in the watersheds.

Figure 3-2 Ottawa River and Lower Maumee Watershed Land Use



Landuse Type	Ottawa Watershed Area (ac)	Ottawa Watershed Area (%)	Lower Maumee Area (ac)	Lower Maumee Area (%)
Agriculture	72,209	57%	497,789	72%
Forest	10,303	8%	60,680	9%
Urban	37,289	30%	124,132	18%
Water	689	1%	9,471	1%
Wetlands	5,163	4%	570	0%
Other	457	0%	6,705	1%
Grand Total	126,112	100%	692,642	100%

Soil and Geology

According to the Lower Maumee Rapid Watershed Assessment, the soils of the watershed include glacial till, lacustrine and beach deposits, glacial outwash, recent alluvium, weathered bedrock, and organic material. The watershed contains 317 different soil types that are nearly level. Very poorly to somewhat poorly drained soils (Soil Groups C and D) predominate but the watershed also includes areas of sandy soils on beach ridges and flats, organic soils in depressional glacial till, and sloping erosive soils (Soil Groups A and B). Some karst features are found in the eastern portion of the Lower Maumee Watershed and limestone quarries are scattered throughout the watershed.

The Oak Openings region of the Lower Maumee watershed encompasses 84,000 acres stretching approximately 22 miles in a 3 to 5 mile-wide band through Lucas, Henry, and Fulton counties in northwest Ohio. This region also extends into the Ottawa River Watershed and into Michigan. Refer to Figure 8-1 for a map showing the Oak Openings region. This geologically unique area is composed of a 20 foot-deep layer of sand deposited from an ancient glacial-melt lake that sits atop an impervious layer of clay. The unusual geologic formation of the Oak Openings region harbors a diverse population of plants that is found nowhere else in the world.

In the Ottawa River Watershed in Michigan's Lenawee County, soil consists of very deep, poorly drained and very poorly drained, moderately slowly or slowly permeable soils that formed in lacustrine deposits. These soils are on lake plains and depressional areas on moraines, outwash plains, and glacial drainageways. Slope gradient ranges from 0 to 2 percent. In Michigan's Monroe County, soils are nearly level, somewhat poorly drained to very poorly drained on lake plains. Soils in northeast Ohio are a mixture of very poorly to somewhat poorly drained soils that have been leveled by wave action on a glacial till plain. Slopes range from 0 to 1 percent.

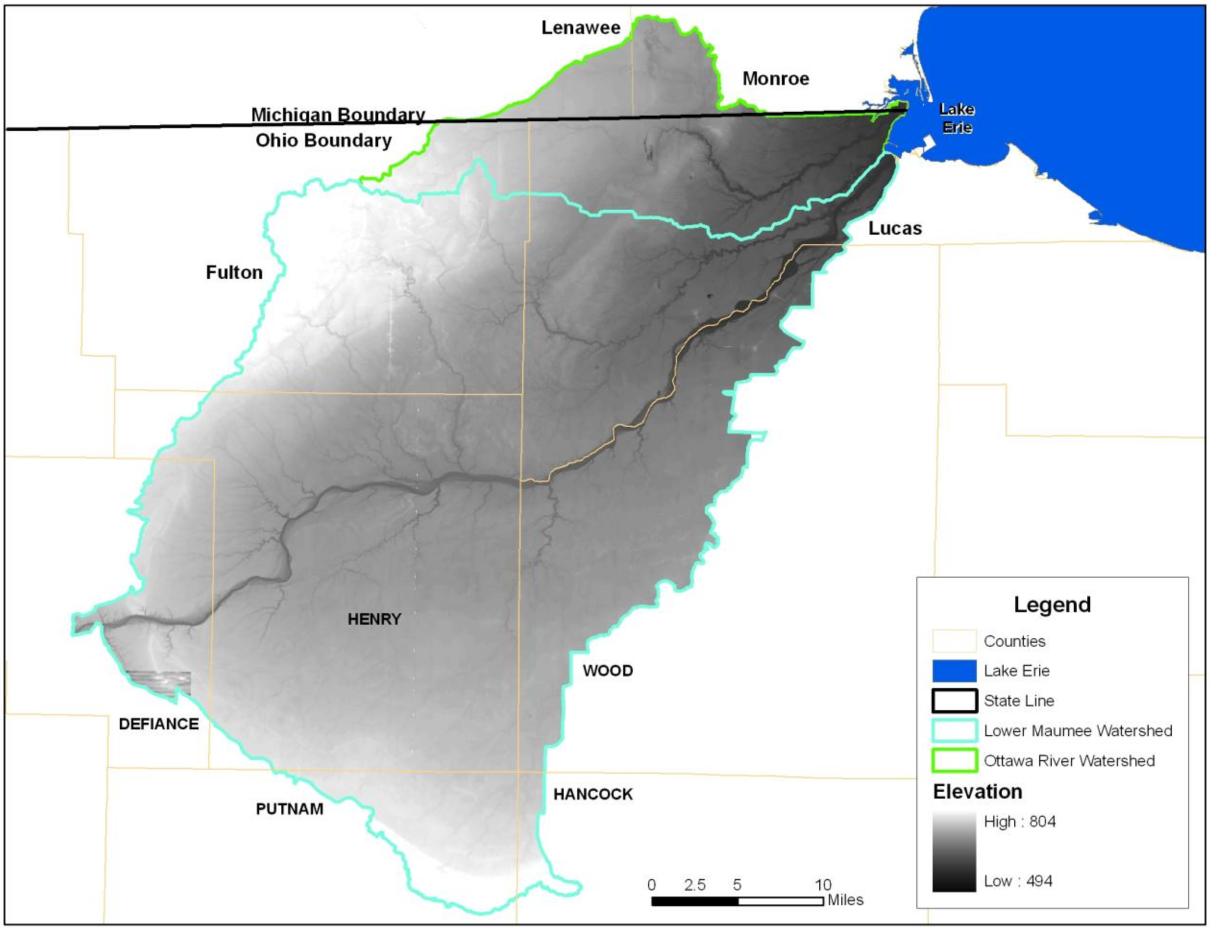
Courtesy of Northwest Ohio Nature

Scout trail at Oak Openings Preserve

Topography

The Lower Maumee and Ottawa River watersheds are characterized by nearly level glacial lake plain with a few scattered sandy ridges that are remnants of past shorelines and moraines. Topographical relief typically varies by less than 10 feet, although beach ridges and moraines occasionally rise up to 30 feet above the general level of the landscape. The land slope of the vast majority of the watersheds is less than 2 percent with most of that falling between a 0 and 1 percent slope (NRCS, 2009). Refer to Figure 3-3 for a digital elevation model of the watershed.

Figure 3-3 Ottawa River and Lower Maumee Watershed Digital Elevation Model



Weather

Although rainfall and temperature varies from region to region and year to year within the Lower Maumee and Ottawa River watersheds, the month of June records the greatest average monthly rainfall (3.8 inches) and the month of February (1.88 inches) the least. Average monthly temperature also varies over portions of the watersheds with the highest average monthly temperature in July (83°F) and the lowest in January (16°F). In an average year, 37 inches of snow falls, usually between late November and early March (Climate of Toledo, Ohio, 2009).

Population

The population of the Lower Maumee and Ottawa River watersheds is estimated at a little over 500,000 persons. The character of the two watersheds is predominately rural with the vast majority of the population centered in Toledo, Sylvania, and Bowling Green, Ohio.

Water Bodies

The Lower Maumee Watershed contains 10,041 acres of open water and wetland, or about 1 percent of the total area of the watershed. The Lower Maumee also contains 1,935 miles of rivers and streams. Data from the Michigan Geographic Data Library and the Ohio DNR listed 5,852 acres of open water and wetland in the Ottawa River Watershed or about 5 percent of the total watershed. The Ottawa River watershed contains 277 miles of rivers and streams.

Impaired Water Bodies

The Ottawa River at Toledo, Ohio, is severely impacted by contaminated sediments. According to the Toledo Metropolitan Area Council of Governments (TMACOG), high concentrations of PCBs and metals in the lower river pose risks to human and ecological health. Contaminated sediments, especially in the Ottawa River, were a primary reason for designating the Maumee River as an Area of Concern (TMACOG, 2007). Total Maximum Daily Load (TMDL) monitoring for the Ten Mile Creek Watershed, a subwatershed of the Ottawa River Watershed, is scheduled for 2014.

According to the Lower Maumee Rapid Watershed Assessment, the Lower Maumee Watershed is only beginning to be evaluated through the EPA's TMDL process. Water quality sampling was initiated in 2006 to determine if a TMDL study was needed.

The Watershed Restoration Plan for the Maumee River Area of Concern (Maumee RAP, 2006) found that the majority of streams in the eastern portion of the watershed are impaired and do not meet water quality standards. The study found that the large rivers rated better for water quality than the smaller streams and impairments did primarily due to non-point source pollution, siltation, and stream alteration.

An example of a stream impaired by non-point source pollution is Swan Creek. Swan Creek is a subwatershed of the Maumee River and covers portions of Lucas, Fulton, and Henry counties. The Swan Creek Watershed TMDL report was approved by USEPA on January 6, 2010. The impairments are attributed to non-point source pollution and habitat degradation associated with farming practices and drainage improvements as well as urban land uses. TMDLs were prepared for nitrate-nitrite, total suspended solids, *Escherichia coli*, total phosphorus, total copper, total aluminum, benzo [a]pyrene, ammonia, dissolved solids, strontium, and dieldrin.

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4.0 SITE ASSESSMENT AND PLANNING

When considering whether and how to apply LID techniques to a specific site, the owner or developer should think of these practices as tools in a tool box. Before picking out a tool, one has to understand the job being done. Some tools will work better than others in a specific situation, just as some LID practices work better than others for specific site conditions. In both cases, one should start with planning the work to be done rather than picking out a tool.

Early planning makes the use of LID easier, less expensive, and more effective. It will also help to think of LID as more than a stormwater management method. There can be multiple benefits from LID, such as community beautification, job creation, reduced emissions through less mowing, mitigating the urban heat island effect, and lowering costs with a sustainable approach.

The process of implementing LID is outlined in Section 4.1. Better site design principles are presented in Section 4.2, and Section 4.3 addresses planning for retrofits to existing stormwater systems.

4.1 Site Assessment for New Development and Redevelopment

4.1.1 LID Implementation Process

The following details the LID implementation process for new development and redevelopment as a series of steps. The process begins with site analysis and continues through design and installation and finally to ongoing operation and maintenance. All of the steps are important, but analysis, especially identifying and prioritizing objectives, is the basis for all of the others (ODNR, 2006; SEMCOG, 2008; Weinstein, *et al*., 2009).

Site Analysis

1. Identify and prioritize the objectives for LID on the site. Each objective should be linked to a reason (driver) or desired outcome. Drivers may include protecting the environment, reducing project costs, or meeting regulatory requirements. Regulatory requirements include combined sewer overflow mitigation, impervious area limits, MS4 stormwater permit compliance, and TMDL implementation. Refer to Chapter 2.0, Regulations, summarizing criteria that may be warranted or required for designing post construction BMPs. Desired outcomes may include reclamation of abandoned lots, community-building, flood control, water reuse, improved water quality, job creation, and historic preservation. Consider watershed-wide goals, but also look for opportunities on and near the site that will make some LID practices more feasible, such as planned street and utility upgrades that could reduce construction costs, urban gardens that could use water collected on site, and the possibilities for linkages to other LID or open space systems.

2. Characterize the site to identify constraints to and opportunities for the application of LID in terms of the objectives and intended land use.

a. Define the development features, the existing and proposed land uses, the land areas to be disturbed, and the areas that affect site hydrology (subwatersheds). Perform a preliminary hydrologic analysis for the pre-construction and post construction cases. Refer to Sidebar 4-1.

b. Inventory natural resources such as waterways and drainage areas that drain to or receive runoff from the site; soils, buffers, slopes, groundwater, wetlands and near-surface geology; wildlife and vegetation.

c. Document man-made features such as utilities, public uses, and roadways on and near the site; applicable stormwater management, zoning, and subdivision regulations, as well as future plans for changes to these.

3. Evaluate candidate practices by developing a conceptual design that merges the drivers and goals with the site constraints and opportunities. The design should include both nonstructural and structural BMPs that are chosen to address the objectives and site characteristics. This process may be iterative, with some practices being rejected and new ideas added as their interactions are considered in more detail. The conceptual design should include a cost analysis for the BMPs in the context of the goals and site characteristics. This may be done using simple cost estimation procedures or with models such as USEPA's SUSTAIN (System for Urban Stormwater Treatment and Analysis Integration) or the Water Environment Research Foundation BMP and LID Whole Life Cost Tools available at **www.werf.org/bmpcost**.

4. Public outreach and involvement, including coordination with regulatory agencies, is encouraged on all sites early in the planning process, but especially where the LID practices may be particularly visible or affect neighboring properties. The owner or developer may uncover opportunities or find reasons to modify the approach by soliciting input from the public. This effort should continue through construction and into the operational phase.

Sidebar 4-1
Hydrologic Analysis for LID

The LID process seeks to mimic or restore the predevelopment hydrology through runoff volume control, peak runoff rate control, flow frequency/ duration control, and water quality control.

The low-impact hydrologic analysis uses site topography (imperviousness, area, slopes, etc.) to estimate the following parameters for the existing (pre-construction) and proposed (post construction) conditions:

- Volume
- Rate of Discharge
- Temporary and Permanent Storage

More detail available in the document *Low Impact Development Hydrologic Analysis,* by Prince Georges County, Maryland, July 1999 **www.epa.gov/owow/nps/lid/lid_hydr.pdf**

Design and Installation

Beginning with the conceptual design, the designer should further define the location and sizing of the BMPs using the project goals, site constraints, and more detailed analysis of the planned development. In general, the following principles apply (ODNR, 2006):

1. Reduce total site impervious areas
2. Integrate preliminary site layout plan

3. Minimize directly connected impervious areas
4. Modify/Increase drainage flow patterns
5. Compare pre- and post-development hydrology, and identify LID BMPs
6. Complete site plan

The process of BMP selection is discussed in more detail in Chapter 5.0. Details of the BMPs and design considerations for each are provided in Chapters 6.0 and 7.0.

During design, maintenance of the BMP should always be considered. Owners of the BMP generally want a facility that is easy and cost-effective to maintain. Considerations should include the need for specialty equipment, availability of manpower (both paid and volunteer), access, cost of trash/sediment disposal, frequency of maintenance, and potential cost of component replacement such as plants or soil.

LID practices can be simple compared to traditional (gray) methods, but require just as much care in the installation phase. BMPs can be damaged by common construction practices, such as compacting soils by using heavy equipment or working in saturated conditions. Construction oversight and inspection by the designer is recommended for quality control and assurance. Public outreach should continue during design and installation. Regular and timely communications with regulatory agencies and neighbors are especially important as these innovative and unfamiliar practices are put in place.

Operation and Maintenance

Similar to having an operation and maintenance (O&M) plan for traditional stormwater systems, water quality BMPs must also have an O&M plan. Owners should establish an O&M plan that describes the procedures for routine maintenance, corrective actions and repairs, and the agency or persons responsible. The fact sheets in Chapters 6.0 and 7.0 include O&M guidance. An O&M budget should be developed and adequate funding set aside.

Monitoring is an important part of O&M. The type and frequency of monitoring will depend on the funds available and the types of BMPs, but should at a minimum include regular inspection. The monitoring results should be documented and reviewed at least annually to determine how well the system goals are being addressed. Besides detecting malfunctions, monitoring can also highlight potential BMP improvements that could enhance effectiveness or reduce O&M efforts.

Public outreach should continue during operation to avoid misunderstandings of these often unfamiliar practices. This outreach may include signs, posters, a website, presentations to community groups, and informal discussions with interested neighbors and the general public.

4.1.2 Special Planning Considerations

When planning to use LID on a new development or redevelopment site, the following issues merit special consideration in the Lower Maumee and Ottawa River Watersheds:

- **Low-Permeability Soils**: Contrary to common perception, LID practices for stormwater management can be successfully implemented in areas with clay soils or highly-compacted urban soils. Infiltration can be promoted by incorporating subsurface storage beneath an infiltration practice (bioretention, bioswale, pervious pavement, etc.) and minimizing surface storage. The depth of surface storage should allow for no more than can draw down below the soil surface within 24 hours. Alternatively, infiltration practices can be modified with an underdrain so that, despite the infiltration rate of the soil or the depth of ponding, the runoff will draw down within 24 hours. Refer to Chapters 5.0, 6.0, and 7.0 for more detail about selecting and designing BMPs in low-permeability soils.
- **High Groundwater Table**: High water table, even seasonally, can restrict the use of BMPs that infiltrate runoff or use underground structures. Depending on the BMP and the site conditions, designers should provide for 2 to 4 feet of separation between the bottom of the BMP and the top of the seasonally high water table elevation. On-site soil evaluation by a qualified professional is highly recommended.
- **Building Foundation and Structures**: BMPs should be located so that they do not cause water to enter or collect near the foundations of buildings or other structures that could be damaged by water.
- **Deed Restrictions on Private Property**: Deed restrictions may be needed, along with homeowner education programs, to ensure that BMPs are maintained on privately-owned individual property parcels.
- **Zoning Variances**: Variances from zoning, subdivision, building, stormwater management, and drainage regulations may be required for downspout disconnection, impervious area reduction (parking lots, road widths, etc.) and other LID BMPs.
- **Snow**: A reasonable amount of snow storage (2 to 3 feet) is acceptable in an LID facility but the designer should be aware that a large pile of snow could cause soil compaction and stunted plant growth due to the weight of the snow and a concentration of de-icing salt, respectively.
- **Public Health**: Public health agencies can help to address the public’s concerns about West Nile Virus and other mosquito-borne diseases. Pools of water that persist for days or weeks may serve as the breeding ground for mosquitoes. Proper design, construction, and maintenance of stormwater management facilities, as well as education and outreach, are needed to minimize or eliminate this issue.
- **Maintenance Access**: Easements may be necessary to give the community access for maintenance on BMPs.

- **Contractor Bids and Guarantees**: Obtaining reasonable contractor bids and performance guarantees may be an issue for some BMPs due to lack of experience and standard construction and material specifications.

Planning on redevelopment sites requires further consideration as follows:

- Prior land use of a site can pose special challenges for the SWP3 designer (refer to Chapter 2.0). Redevelopment sites with prior industrial land use may contain contaminated soils or groundwater, old landfills, underground fuel tanks, abandoned natural gas or oil wells, acid mine drainage, etc. The SWP3 must address these special conditions. Discharging runoff from these areas is typically not permitted, so the SWP3 must find ways to keep the runoff on site or provide treatment (ODNR, 2006). In most cases, additional permits must be obtained from the Ohio EPA, the Ohio Department of Natural Resources or the U.S. Army Corps of Engineers to disturb soils within such areas. When planning a redevelopment, be sure to contact these agencies to determine potential concerns.
- Redevelopment sites also typically contain existing drainage systems. Even in cases when the existing system will be removed and replaced with a new one, there is typically a time period during which disturbed soils can enter the old system. The SWP3 designer must assure that practices are in place to control runoff through both the new and existing systems until the old system is no longer functional.
- Although redevelopment sites may pose special environmental problems, there are benefits to redeveloping a property, such as utilizing the existing infrastructure. Since much of the basic infrastructure serving the site may already be in place, it may significantly reduce the cost of development. In addition, infill development does not create additional impervious area in the watershed and preserves rural open space and communities.
- For industrial redevelopment sites, Ohio EPA has developed the Voluntary Action Program (VAP) in an attempt to remove the environmental and legal barriers that have stalled redevelopment and reuse of contaminated properties. For more details, contact Ohio EPA.

Sidebar 4-2 References for Ordinance and Code Review Methods

American Rivers:
Local Water Policy Innovation: a Road Map for Community Based Stormwater Solutions (2008)
www.americanrivers.org/library/reports-publications/local-water-policy-innovation.html

Center for Watershed Protection:
Better Site Design: A Handbook for Changing Development Rules in Your Community (1998)
www.cwp.org

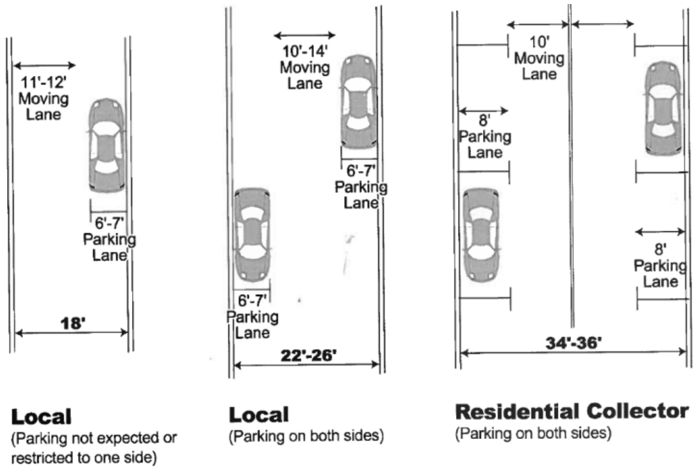
Southeast Michigan Council of Governments (SEMCOG):
Opportunities for Water Resource Protection in Local Plans, Ordinances, and Programs: A Workbook for Local Governments (2002)
http://library.semcog.org/InmagicGenie/DocumentFolder/WaterQualityWorkbook.pdf

USEPA:
Model Ordinances to Protect Local Resources
www.epa.gov/nps/ordinance/mol3.htm
Water Quality Scorecard (833-B-09-004)
http://cfpub.epa.gov/npdes/greeninfrastructure/munichandbook.cfm

4.2 Better Site Design

Planning and design are critical to the successful implementation of LID, but are limited by codes, ordinances, and standards that were developed for traditional (non-sustainable) development practices. In *Better Site Design: A Handbook for Changing Development Rules in Your Community* (1998), the Center for Watershed Protection (CWP, 1998) described an evaluation of impediments to better development and suggested ways to modify rules to remove those barriers. The proposed changes are based on the following model development principles, categorized in three areas or "suburban habitats;" Residential Streets and Parking Lots, Lot Development, and Conservation of Natural Areas. These principles describe the design objective. Consult the Handbook for more details on each principle.

Figure 4-1 Street and Lane Widths



Source: Kulash, 2001

Residential Streets and Parking Lots

These principles focus on those codes, ordinances, and standards that determine the size, shape, and construction of parking lots, roadways, and driveways in the suburban landscape.

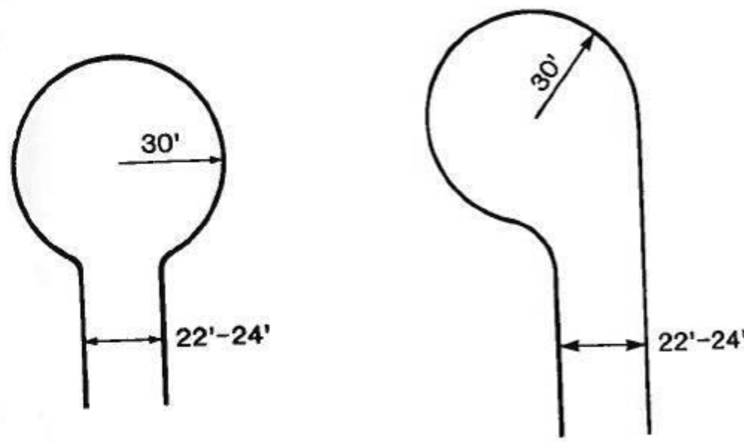
1. Design residential streets for the minimum required pavement width needed to support travel lanes; on-street parking; and emergency, maintenance, and service vehicle access. These widths should be based on traffic volume. Refer to Figure 4-1 for street and lane width recommendations.
2. Reduce the total length of residential streets by examining alternative street layouts to determine the best option for increasing the number of homes per unit length.
3. Wherever possible, residential street right-of-way (ROW) widths should reflect the minimum required to accommodate the travel-way, the sidewalk, and vegetated open channels. Utilities and storm drains should be located within the pavement section of the ROW wherever feasible.
4. Minimize the number of residential street turnarounds (cul-de-sacs) and incorporate landscaped areas to reduce their impervious cover. The radius of turnarounds should be the minimum required to accommodate emergency and maintenance vehicles. Refer to Figure 4-2 for various turnaround configurations.
5. Where density, topography, soils, and slope permit, vegetated open channels should be used in the street ROW to convey and treat stormwater runoff.

6. The required parking ratio governing a particular land use or activity should be enforced as both a maximum and a minimum in order to curb excess parking space construction. Existing parking ratios should be reviewed for conformance taking into account local and national experience to see if lower ratios are warranted and feasible.
7. Parking codes should be revised to lower parking requirements where mass transit is available or enforceable shared parking arrangements are made.
8. Reduce the overall imperviousness associated with parking lots by providing compact car spaces, minimizing stall dimensions, incorporating efficient parking lanes, and using pervious materials in spillover parking areas.
9. Provide meaningful incentives to encourage structured and shared parking to make it more economically viable.
10. Wherever possible, provide stormwater treatment for parking lot runoff using bioretention areas, filter strips, and/or other practices that can be integrated into required landscaping areas and traffic islands.

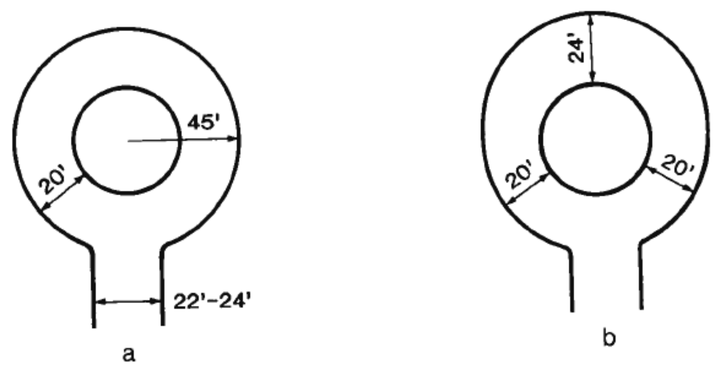
Lot Development

Principles 11 through 16 focus on the regulations which determine lot size, lot shape, housing density, and the overall design and appearance of our neighborhoods.

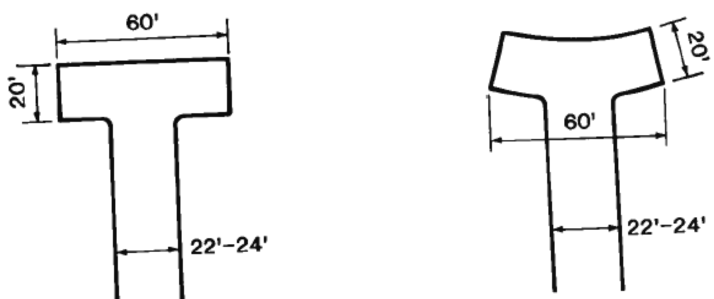
Figure 4-2 Turnaround Configurations



Circular and off-center turnarounds



Circular turnaround with center island



T- and Y-shaped turnarounds

Source: Kulash, 2001

11. Advocate open space development that incorporates smaller lot sizes to minimize total impervious area, reduce total construction costs, conserve natural areas, provide community recreational space, and promote watershed protection.

12. Relax side yard setbacks and allow narrower frontages to reduce total road length in the community and overall site imperviousness. Relax front setback requirements to minimize driveway lengths and reduce overall lot imperviousness.
13. Promote more flexible design standards for residential subdivision sidewalks. Where practical, consider locating sidewalks on only one side of the street and providing common walkways linking pedestrian areas.
14. Reduce overall lot imperviousness by promoting alternative driveway surfaces and shared driveways that connect two or more homes together.
15. Clearly specify how community open space will be managed and designate a sustainable legal entity responsible for managing both natural and recreational open space.
16. Direct rooftop runoff to pervious areas such as yards, open channels, or vegetated areas and avoid routing rooftop runoff to the roadway and the stormwater conveyance system.

Conservation of Natural Areas

The remaining principles address codes and ordinances that promote (or impede) protection of existing natural areas and incorporation of open spaces into new development.

17. Create a variable width, naturally vegetated buffer system along all perennial streams that also encompasses critical environmental features such as the 100-year floodplain, steep slopes and freshwater wetlands.
18. The riparian stream buffer should be preserved or restored with native vegetation that can be maintained throughout the delineation, plan review, construction, and occupancy stages of development.
19. Protect natural areas with a conservation easement. A conservation easement is a

Sidebar 4-3 Incentives for Conservation Development

Density Compensation - Allow greater residential densities *with the implementation of LID t*echniques.

Buffer Averaging - Allow developers to narrow the stream or riparian buffer width at some points if the average buffer width and the overall buffer area meet the minimum criteria.

Property Tax Reduction - Reduce or waive property taxes on an LID project for a given number of years.

Stormwater Credits - Projects that infiltrate X% of stormwater receive up to Y% reduction in the stormwater utility fee

By-Right Open Space Development - When open space development is by-right, an open space plan that meets the requirements of the ordinance goes through the same permit and approval process as a conventional development. The by-right form of development prohibits denial of an open space plan in favor of a conventional plan assuming the open space plan meets the provisions of the ordinance.

Off-site Mitigation - Restoration, creation, enhancement, or preservation occurring outside a project boundary, but within the same watershed.

Natural Area Conservation Credit - Credit may be granted when undisturbed, natural areas are conserved on a site, thereby retaining their pre-development hydrologic and water quality characteristics.

Environmentally Sensitive Development Credit - Targeted toward large lot residential developments that implement a number of Better Site Design practices to reduce stormwater discharges from the development as a whole.

Public Recognition - Emphasize LID projects on website, at Council meetings, and in utility mailers.

voluntary legal agreement between a landowner and a land trust or a government agency that permanently restricts development on private property. This is a valuable tool in protecting natural or traditional use (farming) areas from future development. The conservation easement process may also provide the property owner with a tax benefit.

20. A land donation can also be used as a conservation tool. By donating a piece of property to a conservation organization, the donator can write the property's value off as a charitable contribution. A possible drawback is that grantee may petition to have the land removed from the tax rolls and opt instead to only pay any future special assessments. The land, however, will remain protected in perpetuity.
21. Clearing and grading of forests and native vegetation at a site should be limited to the minimum amount needed to build lots, allow access, and provide fire protection. A fixed portion of any community open space should be managed as protected green space in a consolidated manner.
22. Conserve trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native plants. Wherever practical, manage community open space, street rights-of-way, parking lot islands, and other landscaped areas to promote natural vegetation.
23. Incentives and flexibility in the form of density compensation, buffer averaging, property tax reduction, stormwater credits, and by-right open space development (refer to Sidebar 4-3 for definitions) should be encouraged to promote conservation of stream buffers, forests, meadows, and other areas of environmental value. In addition, off-site mitigation consistent with locally adopted watershed plans should be encouraged.
24. New stormwater outfalls should not discharge unmanaged stormwater into jurisdictional wetlands, sole-source aquifers, or sensitive areas.

4.3 Retrofit Strategies

When a site is being developed for the first time or extensively redeveloped, there are multiple opportunities to install BMPs. However, many opportunities also exist on sites not undergoing development. To address these developed sites, BMPs can be added to the existing infrastructure. Examples of this process, known as retrofitting, include permeable driveways, curb extension rain gardens in streets, bioretention in landscaped areas, enhanced detention basins, downspout disconnection, and vegetated roofs.

Retrofitting can be challenging due to the lack of available space; the need to avoid or relocate structures and utilities; and maintenance of access for parking, pedestrians, and site users. On a unit area basis, LID retrofitting can be more expensive than implementing the same BMPs as part of a development plan.

However, stormwater management issues are so prevalent in the watershed that they will not be adequately addressed if sustainable approaches are confined to new development and redevelopment sites. LID is well-suited to meet the retrofitting challenges because there is a diverse list of BMPs, they are adaptable in size and shape, and they can improve a site by adding aesthetic value. When retrofitting can be implemented as a component of another public works project (partner project), such as a road reconstruction or utility line installation, the costs and complexities can be shared. The LID components could be an added feature of a planned partner project, falling into that project's original footprint, such as pervious pavement or curb extension rain gardens in a reconstructed roadway. In some cases, the LID project could be the starting point that makes the partner project more feasible, such as a greenway or trail along a protected riparian area. Retrofitting opportunities will require careful site characterization, especially in the areas of existing regulatory requirements and site owner/user constraints.

In some cases, such as when LID is especially compatible with the existing site use or provides desired benefits, retrofitting can be easier than new development/redevelopment approaches. One example would be the retrofitting of an existing dry detention basin to a retention basin or extended dry detention basin through planting and hydraulic modifications that improve habitat and water quality for the receiving stream. The detention basin site configuration, accessibility, and established use as a basin would make installation of a retention basin there much simpler than converting another property. The capital costs of retrofitting could be recovered over time through reduced turf mowing costs. The Center for Watershed Protection has developed a *Manual on Urban Stormwater Retrofit Practices*, part of the Urban Subwatershed Restoration Manual Series, which describes the process of identifying, planning, and designing retrofits that will fit into the existing infrastructure and improve water quality sustainably.

5.0 STORMWATER BMP SELECTION

Selection of the BMPs to use on a specific site should begin with the objectives and site characteristics and then match them to the capabilities of the BMPs. The toolbox analogy applies here – plan and define the work to be done before picking out the tools to do the job.

Each BMP has limitations, advantages, and associated costs to be considered. The following is a guide to the considerations a designer should use when selecting BMPs for a specific situation and is adapted from the Michigan LID Manual (SEMCOG, 2008). Refer to Table 5-1 for a matrix to assist in selecting appropriate BMPs for a given set of site characteristics.

Nonstructural BMPs

The process of BMP selection should begin with nonstructural BMPs. These lower-cost, highly-effective practices should be the first measures to apply to the design. Common nonstructural BMPs include minimizing soil compaction and impervious area, protecting sensitive areas, and disconnecting stormwater sources. Nonstructural BMPs should be evaluated in the context of the analysis of drivers, goals, and site characteristics discussed in Chapter 4.0. The BMP selection may be guided by the following questions and issues:

- *How is the property being used?* A residential development may have more applicability for certain nonstructural BMPs than other land uses. For example, cluster development is an applicable BMP for residential development, but may be less used in more urban situations.
- *What natural features are on site?* A thorough site inventory will provide the necessary information to assess the ability to implement many of the BMPs, including preserving sensitive and riparian areas.
- *What local, county, state, and other regulations need to be met?* A review of local, county, state, and other regulations can also provide guidance on selecting the right mix of nonstructural BMPs.

Sidebar 5-1 Cluster Development

Cluster development, or open space development, incorporates grouping new homes onto part of a development parcel so that the remaining land can be preserved as open space. This provides an attractive living environment which may increase the value of the properties.

- National Association of Home Builders

Image Source: Pennsylvania Department of Environmental Protection
www.dep.state.pa.us/earthdaycentral/00/poster_annotations.htm

Chapter 6.0 provides nonstructural BMP fact sheets. Each provides an overview of the BMP along with design guidance, and should be reviewed and applied to the site as part of the BMP selection process.

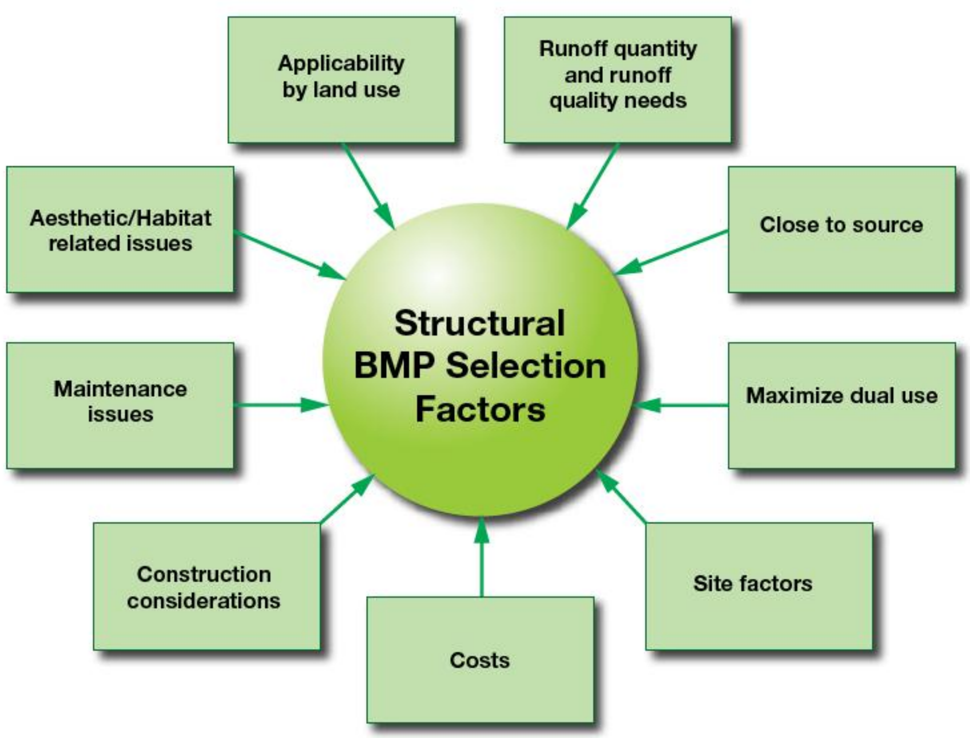
Structural BMPs

Once each of these nonstructural practices has been investigated and applied, a site hydrologic analysis should be conducted to quantify the amount of additional stormwater management needed to meet the requirement or to compare to the predevelopment hydrologic condition. With this knowledge, the network of structural BMPs (see Chapter 7.0) can be designed.

LID involves planning efforts that first prevent as much stormwater runoff as possible on a site, and then mitigate as efficiently as possible, the stormwater that does runoff. Selecting BMPs which accomplish as many stormwater functions as possible is important. Multiple BMPs integrated into a "treatment train" may be needed to meet the goals. For example, proprietary water quality devices and constructed filters, such as a pocket sand filter, are often used in treatment trains to pre-treat runoff before it enters an infiltration-driven BMP. In addition, bioswales and filter strips link well with bioretention, infiltration trenches, and stormwater wetlands in treatment trains.

Not all structural BMPs are appropriate for each site. Selecting from the large and ever-growing list of structural BMPs can be complicated. The successful design process requires balancing technical and nontechnical factors: potential applications, stormwater quality and quantity functions, cost, maintenance, and winter performance for each BMP. Selecting BMPs requires balancing numerous factors, including the following:

Figure 5-1 Structural BMP Selection Factors



Source: SEMCOG, 2008

Runoff quantity and runoff quality needs

BMP selection is often based on the desired removal of pollutants and stormwater runoff. For example, in areas with high phosphorus runoff, infiltration BMPs are excellent choices for removing phosphorus as long as other selection criteria (e.g., site factors) allow for these techniques. Table 5-1 provides guidance relating to BMP performance in terms of runoff volume, groundwater recharge, peak rate, and water quality (total suspended solids, total phosphorous, nitrogen, and temperature).

Close to source

Manage stormwater runoff as close to the source, or origin, as possible. Implementing this factor will vary by site and by the proposed development. For example, distributed bioretention facilities in network with bioswales in a new development can reduce costs by reducing the network of storm sewer pipes and the size of the end-of-pipe flood storage.

Maximize dual use

Consider integrating stormwater management into already disturbed areas (e.g., stormwater recharge beds beneath parking areas, play fields on infiltration basins). This can minimize total disturbed area and, in some cases, provide recreational opportunities for residents or employees.

Site factors

Each site should be inventoried for certain characteristics (e.g., soil type, depth to water table, slopes) which should be incorporated into the BMP selection process. For example, some sites might be characterized by a high water table, surface bedrock, or extremely slow-draining soils, which would make using infiltration BMPs challenging.

Costs

BMP costs include both construction and long-term maintenance activities. Costs are often related to the size and nature of the development. Table 5-1 provides relative cost information. Construction and maintenance costs tend to be site and development specific.

Construction considerations

Many BMPs have construction guidelines to provide additional guidance. For example, locating and properly using excavation equipment is critical during construction of infiltration BMPs to avoid soil compaction. Specifying proper construction materials is also critical, such as requiring washed aggregate in any structural BMP.

Maintenance issues

Ease of maintenance and needed repairs are critical issues to consider in selecting a BMP. Some BMPs require greater maintenance to function properly. However, they may also achieve greater stormwater quantity and quality goals specific to the site objectives. Vegetated BMPs require various types of landscape care. Structural BMPs, such as pervious pavement, require periodic vacuuming, while infiltration trenches and dry wells are likely to require little maintenance. Some BMPs, especially those with plantings, may naturally improve in performance over time as vegetation grows and matures. In any case, maintenance is addressed for each BMP in Table 5-1 and in the Chapter 7.0 fact sheets.

Aesthetic-/Habitat-related issues

Landscape enhancement is becoming an ever-greater goal in most communities and developments. In some cases, developers are willing to pay for BMPs which serve to make their developments more attractive and improve value and marketability. For example, rain gardens make yard areas more attractive. Stormwater wetlands, naturally planted swales, bioretention, vegetated roofs, and many other BMPs can be integrated into landscape design and create value in addition to solving stormwater problems. In addition, many of these BMPs add habitat value and provide other environmental benefits.

Applicability by land use

Some land uses lend themselves to certain BMPs. Low density residential development lacks large congregate parking areas conducive to pervious pavement with infiltration. Conversely, rain barrels are especially good for residential use while larger cisterns are better for commercial/industrial buildings. Successful LID programs strive to match the BMP with the land use and user type, as indicated in Table 5-1.

Cold climate considerations

Another important design consideration is how the BMP will function in our cold climate. Critical aspects of winter conditions are extremely cold temperatures, sustained cold periods, and polluted snowmelt, as well as a short growing season. Extreme cold can cause rapid freezing and burst pipes. Sustained cold can result in development of thick ice or frozen soil layers in some BMPs. On the other hand, the deeper and more persistent the snow layer, the less severe the soil freezing. Water quality problems associated with snow melt occur because of the large volume of water released during rain and snow events. This runoff carries material that has accumulated in the snowpack all winter, as well as material it picks up as it flows over the land's surface. Chloride is the cause of many problems associated with snowmelt runoff. Chloride is a very soluble chemical that migrates easily through treatment systems and soil. To reduce damage to LID BMPs, avoid over-application of chloride and route runoff properly.

Table 5-1 Low Impact Development BMP Selection Guide

		Land Use Applications						Stormwater Quantity Impacts		Stormwater Quality Impacts				Watershed-Specific Performance			Other Selection Indicators		
		Agricultural	Commercial	Industrial	Residential	Road	Ultra Urban	Volume Reduction	Peak Flow Attenuation	TSS	Total Phosphorus	Total Nitrogen	Temperature	Winter Performance	Clay Soils[3]	High Water Table	Hotspots	Maintenance	Cost
Nonstructural BMPs	Protection of Natural Features/Sensitive Areas	Y	Y	Y	Y	Y	Y												
	Tree Canopy	N	Y	LIM	Y	LIM	Y												
	Minimize Impervious Surfaces	Y	Y	LIM	Y	LIM	LIM												
	Stormwater Disconnection	Y	Y	LIM	Y	Y	Y												
	Conservation Landscaping Techniques	Y	Y	Y	Y	LIM	LIM												
	Minimize Soil Compaction	Y	Y	LIM	Y	Y	LIM												
Structural BMPs	Bioretention	Y	Y	Y	Y	Y	Y	M/H	M	H	M	M	H	M	Y	LIM[4]	Y[5]	M	M
	Bioswale	Y	Y	Y	Y	Y	LIM	L/M	L/M	M/H	M/H	M	M	M	Y	Y	N	L/M	L/M
	Filter Strip	Y	Y	Y	Y	Y	LIM	L/M	L	M/H	M/H	M/H[1]	M/H	H	Y	Y	Y	L/M	L
	Permeable Paving	N	Y	LIM	Y	LIM	Y	H	H	H	M/H	L	M/H	M	Y	LIM[4]	N	H	M
	Tree Box	N	Y	Y	Y	Y	Y	M	M	M	L/M	L/M	H	M	Y	Y	Y[5]	M	M
	Infiltration Trench	Y	Y	LIM	Y	Y	Y	M	L/M	H	M/H	L	H	H	LIM	N	Y[5]	L/M	M
	Stormwater Wetlands	Y	Y	Y	Y	LIM	LIM	L	H	H	M	H	L/M	M/H	Y	LIM[4]	LIM[5]	L/M	H
	Dry Wells	Y	Y	LIM	Y	N	LIM	M	M	H	M/H	L	H	H	LIM	N	N	L/M	M

NOTES:

[1] Reported as NO_3.

[2] Rain Barrel - LOW; Cistern – HIGH

[3] Most any BMP can be designed to function in clay soil by using an underdrain or limiting the ponding depth.

[4] Instead of providing a minimum 2-foot separation of the facility from the water table, an impermeable liner with an underdrain could be used. The proximity of the water table to the ground surface dictates whether locating a facility there is worthwhile.

[5] BMPs must use an impermeable liner with an underdrain so infiltration does not occur.

Y=Yes; N=No; LIM=Limited; L=Low; M=Medium; H=High; VAR=Varies; N/A=Not Applicable

		Land Use Applications						Stormwater Quantity Impacts		Stormwater Quality Impacts				Watershed-Specific Performance			Other Selection Indicators		
		Agricultural	Commercial	Industrial	Residential	Road	Ultra Urban	Volume Reduction	Peak Flow Attenuation	TSS	Total Phosphorus	Total Nitrogen	Temperature	Winter Performance	Clay Soils[3]	High Water Table	Hotspots	Maintenance	Cost
Structural BMPs	Pocket Sand Filter	Y	Y	Y	Y	Y	Y	M	L/M	H	M	M	H	M	Y	LIM[4]	Y[5]	M	M
	Vegetated Roof	Y	Y	Y	LIM	N/A	Y	M/H	M	M	M	M	H	M	N/A	N/A	Y	M	M
	Proprietary Devices	Y	Y	Y	Y	Y	Y	N/A	N/A	VAR	VAR	VAR	NONE	H	N/A	N/A	Y	VAR	VAR
	Cisterns	Y	Y	Y	Y	N	Y	H	L	M	M	L	M	M/H	N/A	N/A	Y	M	L/M[2]

Source: Table 5-1 is adapted from the Michigan LID Manual (SEMCOG, 2008).

6.0 NONSTRUCTURAL STORMWATER BMPS

Nonstructural stormwater BMPs should be the first measures to apply to a site design. They are highly-effective in limiting pollutant loads in runoff and tend to lessen the need for the more costly structural BMPs. The nonstructural BMPs presented in this section include the following:

6.1 Protect Natural Features and Sensitive Areas
6.2 Tree Canopy
6.3 Minimize Impervious Surfaces
6.4 Stormwater Disconnection
6.5 Conservation Landscaping Techniques
6.6 Minimize Soil Compaction

6.1 Protect Natural Features and Sensitive Areas

Description

The first step in assessing a site and its stormwater runoff potential involves identifying existing natural features and sensitive areas, including any areas containing dense vegetation or well-established trees. Soils with thick, undisturbed vegetation have a much higher capacity to store and infiltrate runoff than do disturbed soils. Disturbing these areas that provide natural water management should be avoided because of the stormwater benefits that they offer and reestablishment of a mature vegetative community can take decades.

Wetland area

A key component of effective stormwater management is taking advantage of a site's natural infiltration and storage capacity. Maximizing infiltration and storage capacity limits the amount of runoff generated and, therefore, the need for additional structural control practices. Areas with a high potential for infiltration and surface storage are typically characterized by:

- Hydrologic Soil Group A or B;
- Low slopes or depressions; and/or
- Dense vegetation, especially trees.

Sensitive areas, such as wetlands, streams, floodplains, or intact forest, should also be avoided during site development and protected from disturbance. Development in these areas is often restricted by federal, state, and local laws. Disturbing these areas alters the natural hydrology and movement of water through a site, which increases stormwater runoff, complicates stormwater management approaches, and increases the difficulty of achieving natural resource and regulatory goals.

Example Application

Methods to minimize the impact of the construction process and allow for the protection of as much of the existing permeable and natural areas on the site as possible include site fingerprinting and cluster development. Minimizing the amount of site clearing and grading can dramatically reduce the overall hydrologic impacts of site development. Damage to unprotected soil and vegetation can have a significant effect on the ability of the site to handle stormwater runoff and result in increased runoff volumes. These techniques apply primarily to new construction but the principles can be adapted to retrofit and infill projects as well.

Benefits and Limitations

- Able to attenuate flow and reduce volume
- Reduces the amount of structural stormwater controls required
- Maintains hydrologic performance and natural functions
- Requires upfront planning and site evaluations to maximize benefits

Managerial Considerations

Protecting natural features requires a holistic site assessment and modification of conventional site development and construction practices. The placement of buildings or other impervious surfaces on areas with highly permeable soils should be avoided. Buildings and other impervious areas should be constructed on the least permeable soils. If permeable soils must be disturbed by paving, infiltration capacity can be maintained by using permeable paving materials.

Site grading that eliminates depression micro storage capacity should be avoided. Small, natural gradients on site often extend the natural flow pathways of stormwater and increase the potential for additional infiltration. When possible, directing runoff from buildings and paved surfaces toward these pathways and areas with high infiltration capacity permeable soils will reduce runoff volume. Integrating existing drainage patterns into the site plan will help maintain a site's predevelopment hydrologic function. Maintaining existing drainage paths and depression storage allows the velocity of stormwater flow across the site to be decreased and infiltration rates of runoff to increase. Analysis of the existing site drainage patterns during the site assessment phase of the project can help to identify the best locations for buildings, roadways, and stormwater practices.

The best way to define existing drainage patterns is to visit the site during a rain event and to directly observe runoff flowing over the site. If this is impossible, drainage patterns can be inferred from topographic data, though depression storage features, which can play a large role in flow and storage during small storms, are not accurately mapped in topographic surveys.

Protecting natural features preserves vegetation. Vegetative cover provides volume storage of rainfall by retaining water on the surfaces of leaves, branches, and trunks of trees located on the site during and after storm events. This capacity is often overlooked, but on sites with a dense tree canopy it can provide additional volume mitigation.

6.2 Tree Canopy

Description

A tree canopy both intercepts rainfall and evapotranspirates water back into the air, thereby reducing stormwater runoff volume. Evapotranspiration refers to the combined effects of evaporation and transpiration in reducing the volume of water in a vegetated area. Interception is a form of detention and retention storage that occurs when leaves, stems, branches, and leaf litter catch rainfall. In addition, tree roots improve the infiltration capacity of the soil, further reducing runoff potential. Trees may be placed strategically as a buffer, or in flow paths and depressions to adsorb runoff. Trees can also be introduced in urban areas as street trees, which can improve urban aesthetics, provide shade and cooling, and improve air quality in addition to providing stormwater benefits.

Courtesy of City of Minneapolis, Minnesota
Residential tree canopy

Planting trees will reduce the runoff volume and peak discharge rate for a drainage area by lowering its runoff potential. Trees should be planted contiguously to maximize their influence on runoff. A tree canopy is typically assumed to be able to intercept approximately 10 percent of rainfall, however, interception and evapotranspiration will have a greater effect on runoff volume reduction for small, frequently occurring, low intensity storms than for larger, intense events. Planting individual trees scattered across the drainage area will not appreciably reduce the runoff volume or peak discharge rate.

Trees may be placed wherever there is sufficient room for the root zone and the canopy taking into consideration future growth. Planting in a vegetated area will provide the additional benefit of forming a vegetated buffer.

Example Application

Reforestation is the planting of trees in an area that was deforested in the recent past (e.g., an area that was cleared for residential development). Afforestation is planting trees in an area where they were absent for a significant period of time (e.g., an old farm field or a riparian buffer). Plantings may be seeds, seedlings, or semi-mature trees.

Benefits and Limitations

- Able to attenuate flow and reduce volume
- Provides shading and cooling and improves air quality
- Cost effective method of improving environmental conditions

- Requires adequate space for roots to allow for tree development and prevent root damage to structures in urban areas
- In the fall, deciduous trees produce leaf litter that may require management

Managerial Considerations

The site characteristics and time frame for revegetation will influence tree stock selection for introducing trees. Container stock is appropriate for sites exposed to a high amount of stress (e.g., pedestrian traffic, urban areas). Container stock also typically becomes established more quickly than less expensive types of stock. If stress and rapid establishment are not concerns, cuttings, bare roots, or other, less expensive stock may be the most economical choice.

Also, the long-term maintenance and landscaping of the planted area will determine its runoff potential. An area replanted and allowed to grow into a mature stand of trees with little or no clearing of undergrowth will eventually constitute woods or forested area. Similarly, if the ground is grass or another designated groundcover, the planted area will be more typical of a park or open space.

Courtesy of Friends of the Pittsburgh Urban Forest

Measures should be taken to avoid compacting the soil in areas to be planted. Surface roughening may improve seed establishment and moisture retention. Soil amendments can also be used to increase permeability. Mulch can be used to increase water retention, decrease erosion, improve soil stability, and insulate seeds and stock from temperature extremes. Mulching or the use of matting is especially critical on steep slopes to prevent erosion.

Street trees are often given very little space to grow in environments that may be inhospitable. The soil around street trees often becomes compacted during the construction of paved surfaces and minimized as underground utilities encroach on root space. If tree roots are surrounded by compacted soils or are deprived of air and water by impervious streets and sidewalks, their growth will be stunted, their health will decline, and their expected life span will be cut short. By providing adequate soil volume and a good soil mixture, the benefits obtained from a street tree multiply. To obtain a healthy soil volume, trees can be planted in large tree boxes, structural soil, root paths, or manufactured devices such as “silva cells,” which can be used under sidewalks or other paved areas to expand root zones. These allow tree roots the space they need to grow to full size.

Courtesy of Friends of the Pittsburgh Urban Forest

Urban trees with silva cells

Typical maintenance tasks include removal of dead or diseased limbs, checking for interference with utility lines and root heave of paved areas, pruning as necessary, and inspection for evidence of disease. Newly established reforested/afforested areas should be incorporated into the existing program for tree maintenance and inspection. Diseased or dead trees should be replaced as necessary.

Protection from exotic/invader species is a concern. Management strategies for dealing with exotics depend on their growth cycle and the degree to which exotics are already established. Exotics may compete with native trees used to revegetate a site and hinder natural succession.

6.3 Minimize Impervious Surfaces

Description

A key component of minimizing overall site impacts and reducing stormwater impacts is minimizing or reducing impervious surfaces. Roads and parking lots constitute as much as 70 percent of total impervious cover in ultra-urban landscapes, and as much as 80 percent of the directly connected impervious cover. Roads tend to capture and export more stormwater pollutants than other land covers in highly impervious areas, especially for small rainfall events. Approaches to minimize impervious surfaces will often entail an evaluation of the transportation network.

Permeable paver blocks

Typical techniques for impervious surface minimization include limiting roadway lengths and widths, minimizing lot setbacks (which in turn minimize driveway lengths), installing sidewalks on only one side of private roadways, and using alternative materials such as permeable paving blocks or porous pavements. Impervious surfaces can also be minimized through the identification of the smallest possible land area that can be practically impacted or disturbed during site development.

A comprehensive approach to minimizing impervious surfaces may be to plan the layout and road network with respect to the existing hydrologic functions of the land (by preserving wetlands, buffers, high-permeability soils, etc.) and minimize the impervious area when new roads are built. When roads are reconstructed or redeveloped, opportunities to eliminate unnecessary impervious surfaces should be evaluated.

Example Application

Impervious surfaces on a site can be minimized by a number of methods and with appropriate site planning and layout. Commonly used techniques to reduce impervious surfaces include:

- Building vertically rather than horizontally. For example, adding floors to buildings to minimize the building footprint or building multi-level parking garages rather than large surface parking lots
- Clustering development to reduce requirements for roads and preserve green space
- Reducing lot sizes
- Reducing road widths to the minimum necessary for emergency vehicles

- Creating some smaller parking spaces intended for compact cars
- Using permeable pavements in place of traditional impervious surfaces

Benefits and Limitations

- Reduces stormwater volume
- Preserves natural features and sensitive areas
- Promotes increased infiltration
- Can be limited by land use and upfront planning

Managerial Considerations

Many urban and suburban streets, sized to meet code requirements for emergency service vehicles and provide a free flow of traffic, are oversized for their typical everyday functions. The Uniform Fire Code requires that streets have a minimum 20 feet of unobstructed width; a street with parking on both sides would require a width of at least 34 feet. Efforts to reduce impervious surfaces often entail a review and evaluation of codes and ordinances for the presence of barriers.

Minimizing the construction of impervious surfaces and the soil compaction that often accompanies them reduces the runoff volume and peak discharge rate and preserves the hydrologic function on a site. Water quality benefits gained through impervious surface reduction are attributed to the decrease in stormwater volume. Sites with a lower percentage of impervious surfaces infiltrate larger volumes of stormwater and maintain a more natural flow regime than conventionally developed sites. Pollution generation, concentration, and transport are also minimized by the decreased use of impervious surfaces.

References

National Research Council, *Urban Stormwater Management in the United States*, October 2008.

6.4 Stormwater Disconnection

Description

Runoff from connected impervious surfaces commonly flows directly to a stormwater sewer system with no possibility for infiltration into the soil. For example, roofs and sidewalks commonly drain onto parking lots, and the runoff is conveyed by the curb and gutter to the nearest storm inlet. Runoff from numerous impervious drainage areas may converge, combining their volumes, peak runoff rates, and pollutant loads. Disconnection decouples roof leaders and downspouts, roadways, and other impervious areas from conventional stormwater conveyance systems, allowing runoff to be collected and managed on-site or dispersed into the landscape. Runoff is redirected onto pervious surfaces such as vegetated areas, reducing the amount of directly connected impervious area and potentially reducing the runoff volume and pollutant load.

Disconnected downspout

Routing runoff to vegetated areas will reduce the peak discharge and stormwater volume by providing an opportunity for infiltration and evapotranspiration. By spreading runoff out, infiltrating it over pervious surfaces, and directing it to stormwater management practices, the amount of stormwater discharged from a site can be significantly decreased. The impact of disconnection on stormwater volume and peak discharge is dependent upon the area to which the stormwater is directed and its ability to infiltrate or evapotranspirate the collected runoff.

Example Application

Several techniques can be used for stormwater disconnection. One of the most common practices is directing roof downspouts to pervious vegetated areas or bioretention systems rather than the stormwater collection system. In addition, parking lots and roads can be designed to direct runoff to swales or bioretention systems instead of along gutters to stormwater inlets. In these cases, eliminating the direct connection between the impervious surface and the collection system provides opportunities for the amount of discharged stormwater to be reduced and provides opportunities for the runoff to be treated in vegetated areas.

Benefits and Limitations

- Attenuates stormwater volume and peak flow rates
- Promotes increased infiltration
- Needs to be designed to limit impacts on structures and building foundations

Managerial Considerations

Disconnection of impervious surfaces such as roofs and parking lots will reduce the peak discharge rate by increasing the flow pathways and the time of concentration as the runoff is directed to permeable areas. Lowering runoff velocities with disconnection results in greater contact time with the soil, potentially increasing the volume of runoff infiltrated during a storm event.

Disconnection practices may be applied in almost any location, but impervious surfaces must discharge into a suitable receiving area for the practices to be effective. Runoff must not flow toward building foundations or onto adjacent private property. Typical receiving areas for disconnected impervious runoff include vegetated stormwater management practices (e.g., filter strips, bioretention) and other existing landscaping such as shrubs.

Typical methods of disconnection may include curb cuts to encourage stormwater flows away from inlets, and open area modifications to enhance the infiltration characteristics of receiving areas. Other modifications include flow spreading and leveling devices, which may be used to encourage sheet flow across vegetated areas. Soil amendments to increase soil permeability are also a possible design option. Disconnecting roof leaders requires simple modifications that route the concentrated flow from roof drains to a permeable area that will allow infiltration instead of discharging it onto an impervious surface. Rock or splash blocks can be used to slow and spread concentrated downspout flow. To protect foundations, downspout flows should be directed at least 4 feet away from the building. Soil amendments, compost, or aeration can also be considered to increase the infiltration capacity of the receiving area.

There is little maintenance associated with disconnection practices. Related maintenance activities are primarily focused on the areas designated to receive stormwater runoff. Engineered infiltration areas should be routinely checked to ensure that they are free of debris and trash. Both vegetated and constructed infiltration areas should be inspected for sediment accumulation. Additionally, receiving areas should be inspected for signs of channelized flow and signs of compaction. Refer to Chapter 7.0 for more detail on designing structural BMPs.

6.5 Conservation Landscaping Techniques

Description

Conservation landscaping uses native trees, shrubs, grasses, or other groundcover that may be more disease-resistant and require less maintenance than non-native species. The plant communities native to an ecosystem have specifically adapted to the climate and hydrologic regime unique to that region. Maximizing plant cover will improve the ability of the site to manage stormwater and minimize runoff. Native vegetation will also maximize the successful establishment of plantings and minimize the need for supplemental irrigation. Refer to Chapter 8.0 for more information about native plants in the Lower Maumee and Ottawa River watersheds.

Native vegetation

Plants have multiple impacts on downstream water quality. First, the presence of a plant canopy (plus associated leaf litter and other organic matter that accumulate below the plants) can intercept rainfall, which reduces the erosive potential of precipitation. With less eroded material going to receiving waters, turbidity, chemical pollution, and sedimentation are reduced. Second, a healthy plant and soil community can help remediate chemical pollutants and filter particulate matter as water percolates into the soil. This occurs through the physical action of water movement through the soil, as well as through biological activity by plants and the soil microbial community that is supported by plants. Third, thick vegetative cover can maintain and improve soil infiltration rates.

Landscaping and planting vegetation will reduce the runoff volume and peak discharge rate for the drainage area by lowering its runoff potential. Stormwater volume reductions result from rainfall interception by leaves and increased evapotranspiration. Interception and evapotranspiration will have a greater effect on runoff volume reduction for small, frequently occurring, low intensity storm events.

In addition to plant selection and landscape design, soil preparation is also a critical factor determining runoff reduction. Soil conditions most favorable to plant growth generally also provide the greatest runoff volume reduction. Soils must be loose enough to allow water to percolate and roots to penetrate. Where these conditions do not exist naturally, soil amendments can be used to increase permeability.

Example Application

The required maintenance level for the site will guide the plant selection. If the site requires frequent mowing or fertilization, has high foot traffic, or has high aesthetic requirements, it should be considered high maintenance and perennials may be a more appropriate planting selection. Low maintenance sites may use grass/legume mixtures. In general, seed mixtures should be chosen based on average soil moisture and sun exposure.

Benefits and Limitations

- Erosion control and soil stabilization
- Runoff volume reduction
- Water quality treatment
- Habitat creation
- Aesthetic enhancements
- Creation of, or addition to, local greenways and wildlife corridors
- Reduction of water demands for landscaping

Managerial Considerations

Landscape and vegetate a site within 30 days after creating the final grade unless temporary stabilization is used. Basic materials include seeds, tree and shrub stock (bare root, container, cuttings, or seedlings), and netting or mulch. Plants include trees, shrubs, and groundcovers such as native grasses, legumes (nitrogen fixing plants), and forbs (e.g., wildflowers). Native groundcovers are a desirable alternative to standard turf.

Interseeding (seeding among existing plant growth, especially grasses) is a sound initial approach to plant establishment. Interseeding should be performed in the fall or early spring. Clearing and grubbing may not be necessary unless a site is densely populated with exotic or invasive species. Incorporate seeds into the soil through raking, harrowing, disking, or drilling.

If tree stock is to be used, the site characteristics and time frame for revegetation will influence stock selection. Container stock is appropriate for sites exposed to a high amount of stress. Container stock also typically becomes established more quickly than less expensive types of stock. If stress and rapid establishment are not concerns, cuttings, bare roots, or other, less expensive stock may be the most economical choice, as long as enough are planted to ensure survival across the site. The time of year chosen for planting stock depends on the type of stock and nursery availability.

Soil in areas to be landscaped should not be compacted. Surface roughening may improve seed establishment and moisture retention. Soil amendments can also be used to increase permeability, and should be applied to areas to be landscaped as far in advance as possible. Mulch can be used to increase water retention, decrease erosion and improve soil stability, and insulate seeds and stock from temperature extremes. Mulching or the use of matting is especially critical on steep slopes.

Watering of vegetation may be necessary during dry periods and occasional replanting may also be required. Reseed or replant any areas where vegetation did not become established. Maintenance requirements for native vegetation are relatively low because native plants are already adapted to regional stressors such as climate and endemic diseases. Protection from exotic/invader species is a maintenance concern. Management strategies for dealing with exotics depend on their growth cycle and the degree to which exotics are already established.

The long-term objectives for the site, in addition to surrounding land uses, will guide the maintenance regime. Sites at which it is desirable to maintain grasses, forbs, or legumes should be mowed. If the site is not mowed, shrubs and trees will replace the groundcover through natural succession, as long as exotics are kept under control. Inspect the site for signs of disease, invasive species establishment, and erosion. Perform inspections annually in late spring. Replace plants and stabilize soil as necessary.

6.6 Minimize Soil Compaction

Description

Minimizing soil compaction can have significant impacts on site hydrology and stormwater runoff. A soil's porosity significantly influences its water retention capabilities. Pore space comprises 40 to 55 percent of the soil volume in undisturbed soils. Even uncompacted clay soils have a certain amount of porosity which should not be disregarded when planning for stormwater management or preservation construction practices. When soil is compacted, the amount of pore space is diminished and the ability of the soil to infiltrate and hold water is reduced.

Courtesy of Friends of Bidwell Park

Evidence of soil compaction

Bulk density, the mass of dry soil divided by its volume, is often used to predict porosity. The surface bulk density of typical undisturbed soils is 1.1 to 1.4 grams per cubic centimeter (gms/cc). The bulk densities of urban soils are much higher because of soil compaction typical of construction practices and urban uses. Many urban open spaces, while appearing "green" and functional, have experienced significant alterations and do not function as natural areas. The bulk density of urban lawns can range from 1.5 to 1.9 gms/cc; fill soils range from 1.8 to 2.0 gms/cc; soils adjacent to buildings and within road rights-of-way range from 1.5 to 2.1 gms/cc. The bulk density of concrete is 2.2 gms/cc. The ability of soils with this level of compaction to infiltrate and retain stormwater is greatly diminished and results in greater quantities of runoff. The runoff of compacted urban soils often resembles that of impervious surfaces, especially for larger storm events.

The decrease in soil porosity in urban soils also negatively impacts the ability of plant roots to penetrate the subsurface. Roots have difficulty penetrating soils with bulk densities 1.6 gms/cc or greater. The inability of compacted soils to both allow roots to grow and to hold water makes it difficult for the soil to sustain vegetative growth. Decreased vegetation on compacted soils reduces the interception of rainfall and management of stormwater.

Example Application

Minimizing soil compaction can be accomplished in a number of ways including: reducing overall paved areas and the associated compaction of permeable soils; minimizing construction easements and material storage areas; providing appropriate construction sequencing; preserving existing trees through site design and layout; and maintaining existing topography and flow paths.

Benefits and Limitations

- Increased infiltration and water retention

- Runoff volume reduction
- Increased ability to grow and sustain vegetation
- Water quality treatment

Managerial Considerations

Minimizing soil compaction involves techniques to preserve the existing characteristics of a site and others designed to restore the function of disturbed locations. For instance, site fingerprinting can be used to minimize ground disturbance by identifying the smallest possible land area that can practically be impacted during site development. Minimizing the amount of site clearing and grading reduces the overall hydrologic impacts of site development. Ground disturbance is typically confined to areas where structures, roads, and rights-of-way will exist after construction is complete. Development is also placed away from environmentally sensitive areas, future open space, tree save areas, future restoration areas, and temporary and permanent vegetative forest buffer zones. Existing vegetated or open space may be preserved instead of clearing a portion of the site in order to create lawn areas.

By minimizing soil compaction, minimizing the construction of impervious surfaces, and preserving the maximum amount of pervious area, site fingerprinting reduces the runoff volume and peak discharge rate. Water quality benefits are also gained because site fingerprinting allows increased infiltration of stormwater and the maintenance of a more natural flow regime than conventionally developed sites. Pollution generation, concentration, and transport are also minimized.

Soil amendments are used to enhance the properties of native soils or restore previously disturbed soils. Soil amendments, which include both soil conditioners and fertilizers, make the soil more suitable for the growth of plants and increase water retention capabilities. By changing the physical, chemical, and biological characteristics of the soil, amendments allow it to more effectively reduce runoff volume and filter pollutants. Soil amendments are valuable in areas with poor soils because they can help add available plant nutrients and

Sidebar 6-1
Soil Amendment Guidance

Conduct a soil analysis of the native soil to determine the optimum quantity for each amendment.

Compost. The amount of compost to be applied depends upon the organic content of the existing soil as well as the proposed soil amendment. Compost typically has an organic content of 45 to 60%. A final organic content of amended soil is 8 to 13% by soil weight. As a rule, a 2-to-1 ratio of existing soil to compost, by loose volume, will achieve the desired organics level. Other common organic amendments include mulch and coir fiber (coconut fiber).

***Gypsum*.** Hydrated calcium sulfate ($CaSO_4 \bullet 2H_2O$) is sometimes applied to soil to increase calcium and sulfur without affecting the pH, as well as to enhance a soil's structure in high clay content soils.

Nutrients and Lime. If the soil pH is below 6.0, the addition of pelletized dolomite is recommended, with application rates in the range of 50 to 100 pounds per 1,000 sq ft. Nitrogen requirements usually range from 2 to 8 pounds per 1,000 sq ft. annually, with slow release water-insoluble forms being the preferred method. Other soil additions may include sulfur and boron with the amount needed determined by soil analysis.

For more details, refer to Chollak and Rosenfeld, 1998.

sustain vegetative cover, reduce long-term erosion, and help reduce runoff peak volumes and discharges by absorption of rainfall and runoff. Refer to Sidebar 6-1 for more information about specific amendments.

Soil amendments increase the spacing between soil particles so that the soil can absorb and hold more moisture. Studies have indicated an increase in total soil storage capacity of 65 percent in compost amended soils. Amended soils have the ability to remove pollutants through sorption, precipitation, filtering, and bacterial and chemical degradation. Also, the decrease in runoff volume improves water quality by reducing pollutant mass transport. Finally, compost materials used for amendments are less prone to erosion than topsoil or compacted subsoil decreasing sedimentation. Soil amendments can improve the water retention capacity and properties of almost any soil but have the greatest impact in areas with poorly draining native soils.

Routine inspections of soils should evaluate factors that may decrease the soil's infiltration capacity. Typical concerns include areas subject to compaction, hydric or waterlogged soils, poor cover conditions, and increased development. In addition, a routine soil infiltration rate analysis of soils in potential problem areas is recommended. Corrective actions for soils that have experienced disturbance involve restoring the infiltration capacity of the soil by aeration, deep tilling, and adding amendments. Reductions in infiltration capacity typically result from compaction or extensive root matting of groundcovers, such as grasses.

References

Chollak, T. and Rosenfeld, P. (1998). *Guidelines For Landscaping with Compost-Amended Soils.* University of Washington College of Forest Resources.

Schueler, T. R., Holland, H. K. (2000). *The Practice of Watershed Protection: Article 36 – The Compaction of Urban Soils.* Ellicott City, MD: Center for Watershed Protection.

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7.0 STRUCTURAL STORMWATER BMPS

Once nonstructural practices have been investigated and applied, a site hydrologic analysis is conducted to quantify the amount of additional stormwater management needed to meet the requirement or to compare to the predevelopment hydrologic condition. With this knowledge, the network of structural stormwater BMPs can be designed. Structural stormwater BMPs used in the LID-sense are typically located to treat stormwater at or near the point of generation. The structural BMPs presented in this section include the following:

7.1 Bioretention
7.2 Bioswale
7.3 Filter Strip
7.4 Permeable Paving
7.5 Tree Box
7.6 Infiltration Trench
7.7 Stormwater Wetlands
7.8 Dry Wells
7.9 Pocket Sand Filter
7.10 Vegetated Roof
7.11 Proprietary Devices
7.12 Cisterns and Rain Barrels

7.1 Bioretention

Description

Bioretention describes a shallow stormwater basin or landscaped area that utilizes engineered soils and vegetation to capture and treat runoff. Also referred to as a rain garden.

Bioretention at an office building

Benefits and Limitations

- Uses biological, chemical, and physical processes to remove a variety of pollutants
- Able to attenuate flow and reduce volume
- Good retrofit capability
- Applicable to small drainage areas
- Good for highly impervious areas
- Relatively low maintenance requirements
- Can be a landscape feature
- Can be a challenge for areas with steep slopes

Suitable Applications

There are numerous design applications for bioretention. These include use on single-family residential lots, on commercial/industrial sites, as off-line facilities adjacent to parking lots, and along highways and roads.

Bioretention areas are designed primarily for the removal of stormwater pollutants from runoff. Bioretention can provide limited runoff quantity control, particularly for smaller storm events. These facilities may sometimes be used to partially or completely meet channel protection requirements on smaller sites. However, bioretention will typically need to be used in conjunction with other structural controls to provide flood protection. Bioretention areas need to be designed to safely bypass higher flows.

Sidebar 7-1 Determine Size of Bioretention Area

A = (WQv) (d) / [(k) (h + d) (t)]

A = surface area of ponding area (ft^2)

WQv = water quality volume (ft^3)

d = filter bed depth (ft)

k = coefficient of permeability of filter media (ft/day) (use 0.5 ft/day for silt-loam)

h = average height of water above filter bed (ft)

t = design filter bed drain time (days) (less than 24 hours is recommended)

Required Design Data

- Stormwater quality and quantity design criteria
- Site characteristics
- Drainage area
- Native soil infiltration rate

Design Guidelines

Location and Siting

- Bioretention areas should have a contributing drainage area less than two acres. Use multiple bioretention areas for larger sites.
- The bioretention surface area is generally between 4 and 7 percent of the contributing drainage area.
- Applicable to sites with soils of sufficient hydraulic conductivity or a suitable outlet for an underdrain system to fully drain the practice in a period of approximately 24 to 48 hours.
- Not applicable where groundwater flow will prevent the basin from draining between storm events.
- In locations where groundwater pollution potential is high due to high pollution loads, high ground water table or extremely permeable soils, an impermeable liner is required.
- Bioretention area locations should be integrated into the site planning process, and aesthetic considerations should be taken into account during siting and design.
- Facility elevations (inlet, outlet, overflow) must be carefully worked out to ensure that the desired runoff flow enters the facility with no more than the maximum design depth.
- Adhere to local setbacks from important infrastructure. At a minimum: 2 feet from property lines, 100 feet from wells, 50 feet from septic systems, 25 feet from building foundations

Regulatory Criteria

The primary treatment volume is limited to the Water Quality volume (WQv) per Ohio EPA.

Physical Specifications

- A minimum of 2 feet of separation is recommended between the water table and the bioretention practice.
- Depth of ponding should be less than 6 inches, but may be up to 12 inches provided ponding will not damage plant materials or nearby structures.
- Designs should include a mechanism to dissipate the energy from the flow entering the facility or provide erosion control. Mechanisms to consider include a riprap or stone apron, multiple inlets, a plunge pool, or a proprietary erosion control device.
- The growing medium can range in depth from 1.5 to 4 feet depending on utility conflicts, budget, plant requirements, condition of native soil, and pollutant removal goals. Studies have shown that growing medium depth and infiltration rate affect pollutant removal (Hunt and Lord, 2006). Consider specifying that the contractor use a ripper or sub-soiler to break up 2 feet of native soil beneath the growing medium to increase treatment, storage, and infiltration capabilities.

  Growing medium should be sandy loam, loamy sand, or loam texture with a clay content ranging from 10 to 25 percent. The soil should have an infiltration rate of at least 0.5 inches per hour and a pH between 5.5 and 6.5. In addition, the growing medium should have a 1.5 to 3 percent organic content and a maximum 500 ppm concentration of soluble salts.
- The underdrain collection system, if deemed necessary, is a 6- to 8-inch perforated pipe (typically with a sock) in a gravel layer. The depth of the gravel layer depends on the desired storage capacity but is typically at least 12 inches. If root growth is expected, PVC pipe is recommended so that a rooter can be used to clear the pipe.
- Use a gradation of stone or a permeable filter fabric to separate the soil layer from the subsurface gravel layer.
- Two to three inches of fine shredded hardwood mulch should be placed around plants and over soil.
- Native and non-invasive plant species are the best for the overall effectiveness of the practice. Alternatively, grass, trees and shrubs may be used.
- On sites with clay soils or compacted soils, the bioretention facility can be designed with a subsurface storage layer sized to store the water quality volume from its contributing drainage area. The ponding depth should be restricted to a depth that will drain below the soil surface in approximately 24 hours based on the infiltration rate of the existing soil, which should be measured at the location of the bioretention facility with a double-ring infiltrometer or other approved method of testing. Clay soils infiltrate at a rate of about 0.05 inches per hour which is just over 1 inch over a 24-hour period. In combination with subsurface storage or as an alternative, an underdrain could be used as an outlet. In low-permeability soils where infiltration is relied upon for the outlet, it is particularly important to include an effective sediment removal mechanism so as not to plug the subsurface storage layer or underlying existing soils.
- Salt tolerant vegetation should be used where road salt is used for de-icing.

Emergency Spillway

An overflow structure and nonerosive overflow channel must be provided to safely pass flows that exceed the capacity of the facility to a stabilized downstream area. If a system is located off-line, the overflow should be set above the shallow ponding limit but below areas that should be protected from flooding.

Pretreatment

Install pretreatment such as a grass filter strip, sediment forebay, or grass channel upstream of the practice.

Operation and Maintenance

Provide adequate access for bioretention facilities for inspection, maintenance, and landscaping upkeep. Regular inspection and maintenance is critical to the effective operation of the facility.

Table 7-1 Bioretention: Typical Maintenance

Activity	Schedule
• Water plants as necessary during the first growing season • Prune and weed plants and remove and replace unsuccessful or diseased plants • Remove trash and debris • Mulch replacement and/or seeding when erosion is evident	As needed
• Inspect pretreatment, inlet, and outlet for clogging	Semi-annually
• Inspect device for winter salting damage	Annually
• Replace mulch 2 inches thick over entire area	2 to 3 years

Depending on the season and type of vegetation, irrigation may be needed during plant establishment. These factors will also determine the irrigation frequency. “Established” means that the soil cover has been maintained for at least one year since replanting. Native plants may require less irrigation than non-natives. In periods of extended drought, temporary supplemental irrigation may be used to maintain plant vitality.

Example Applications

Curb Extension Bioretention

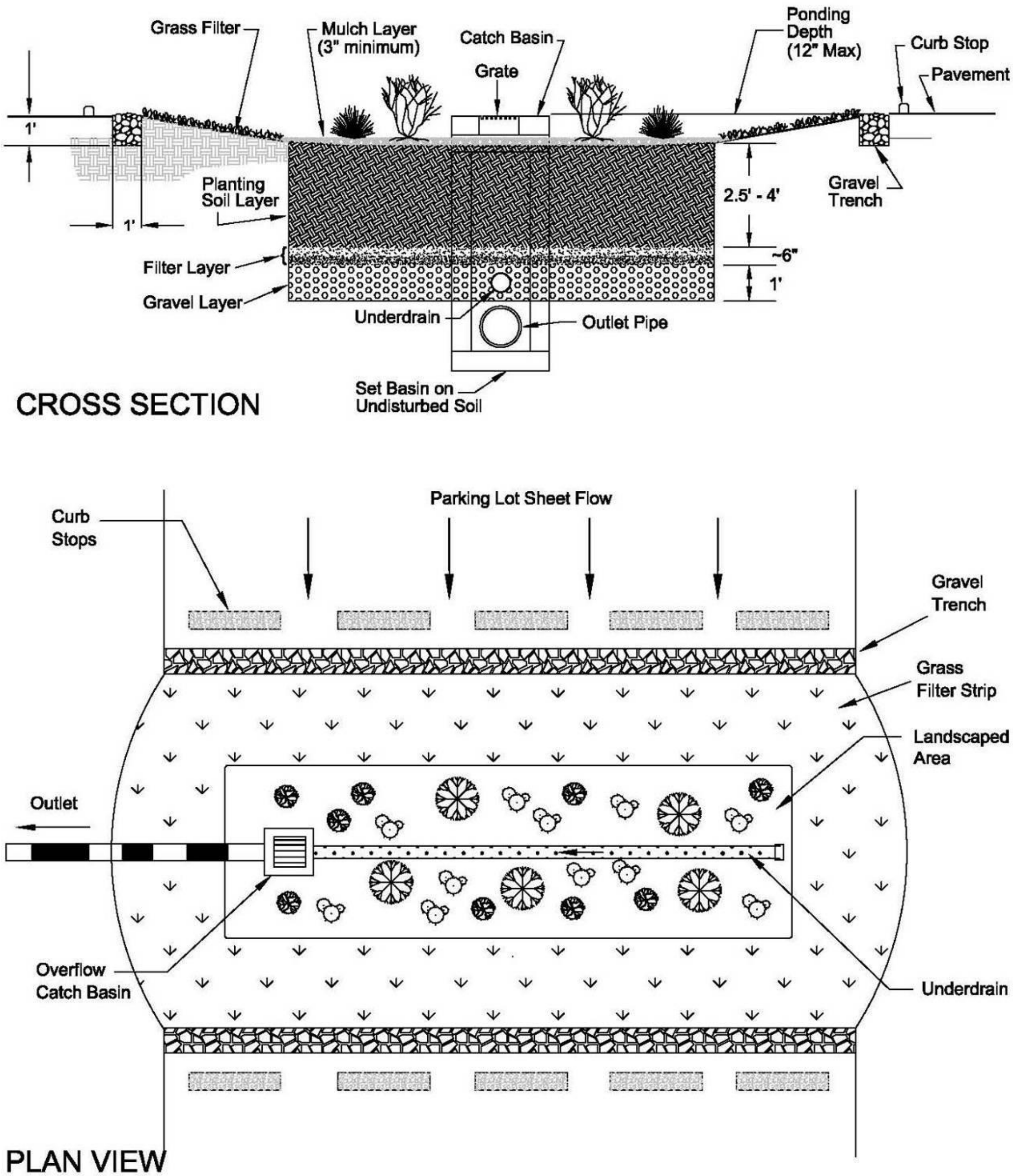
Single-Family Residential Rain Garden

Parking Lot Bioretention

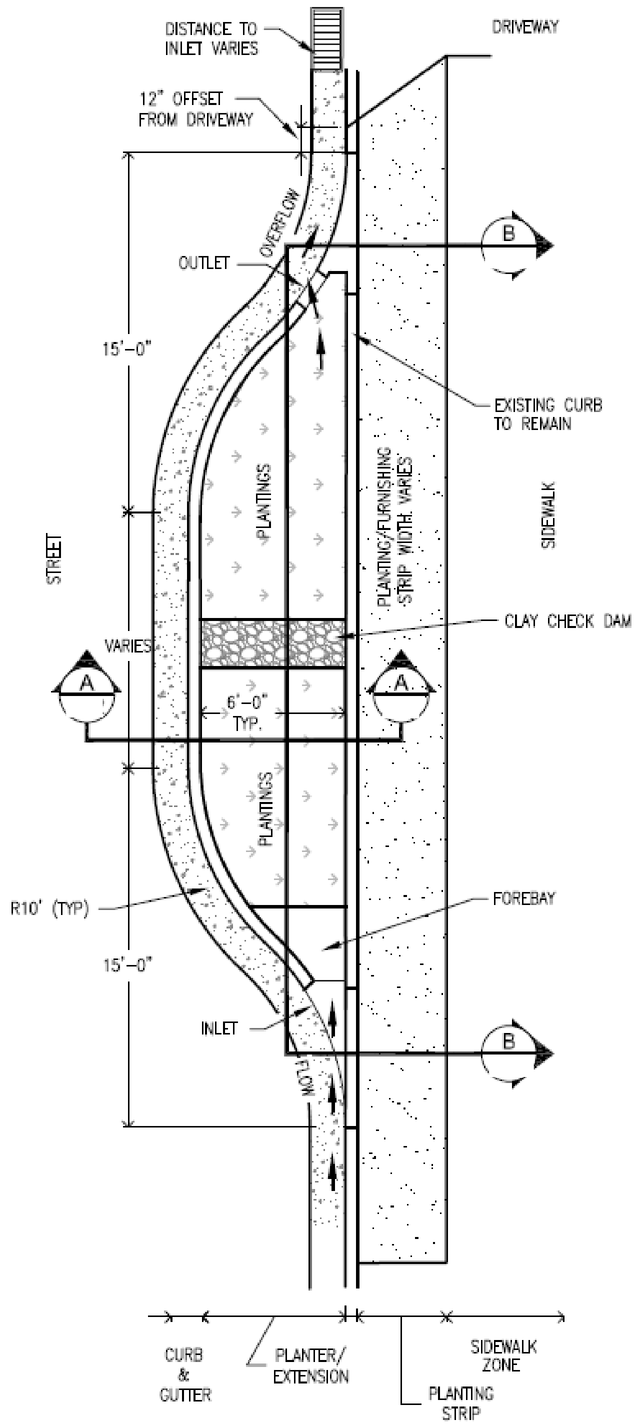
Urban Bioretention Applications

Example Design Details

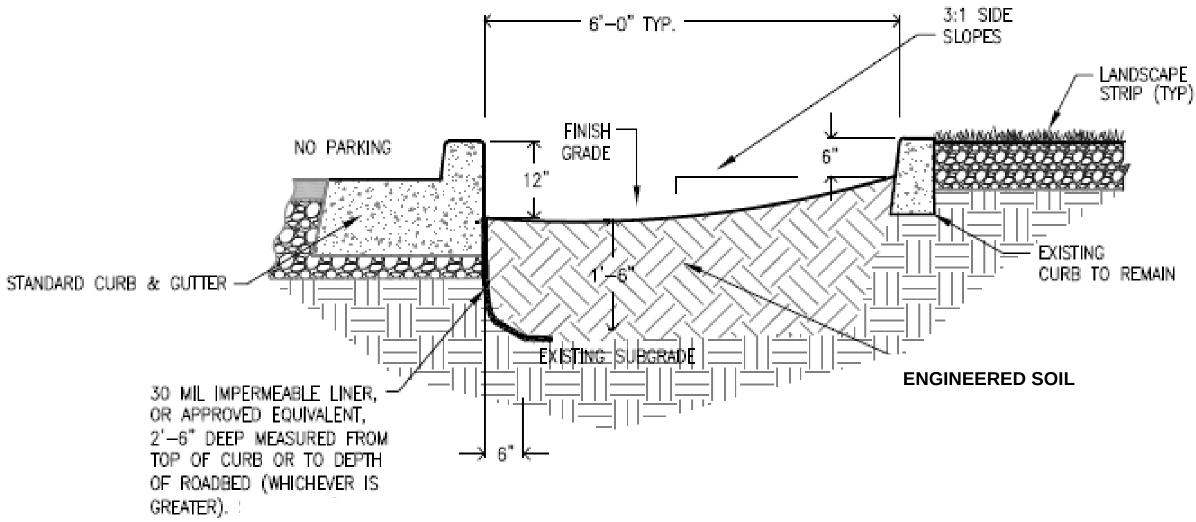
Bioretention Details (ODNR, 2006)



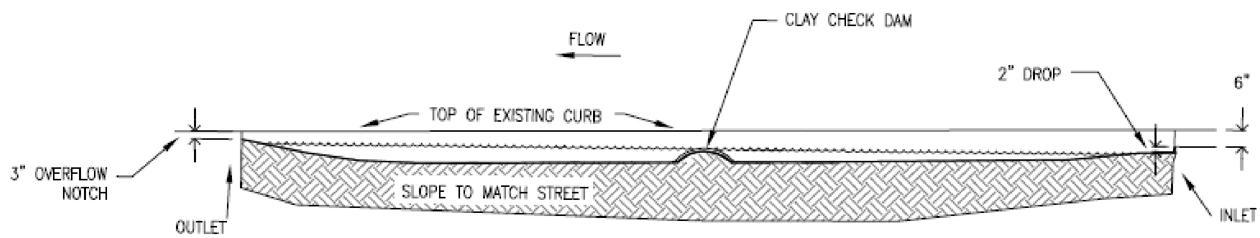
Curb Extension Bioretention Details (City of Portland, Oregon)



CURB EXTENSION PLAN



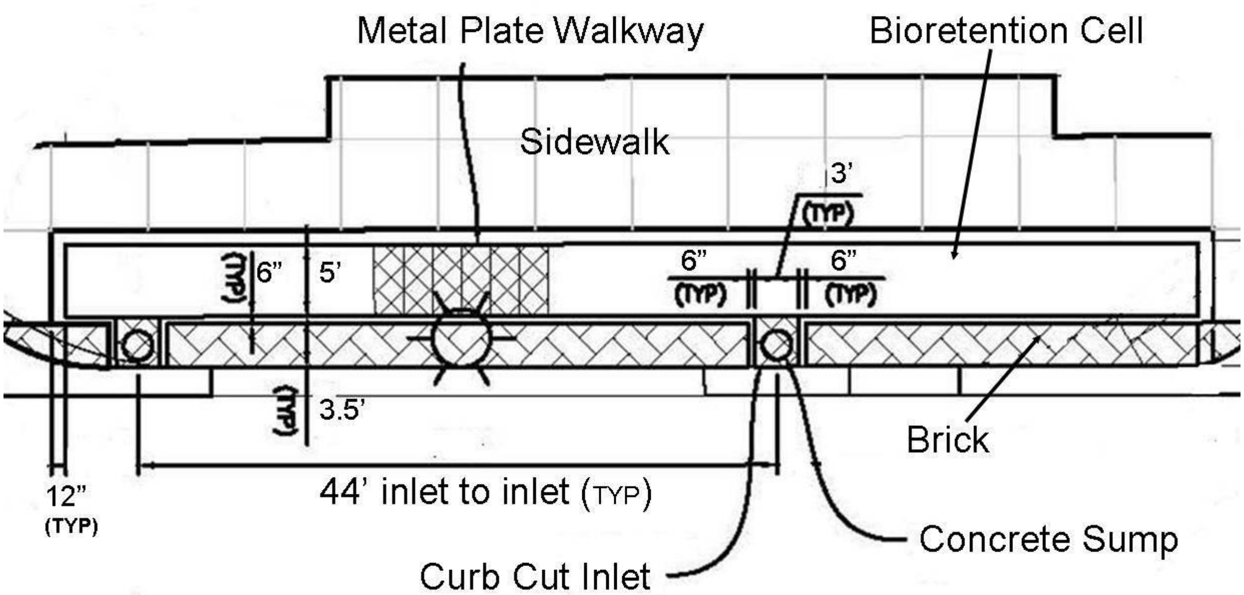
SECTION A-A
CURB EXTENSION SECTION

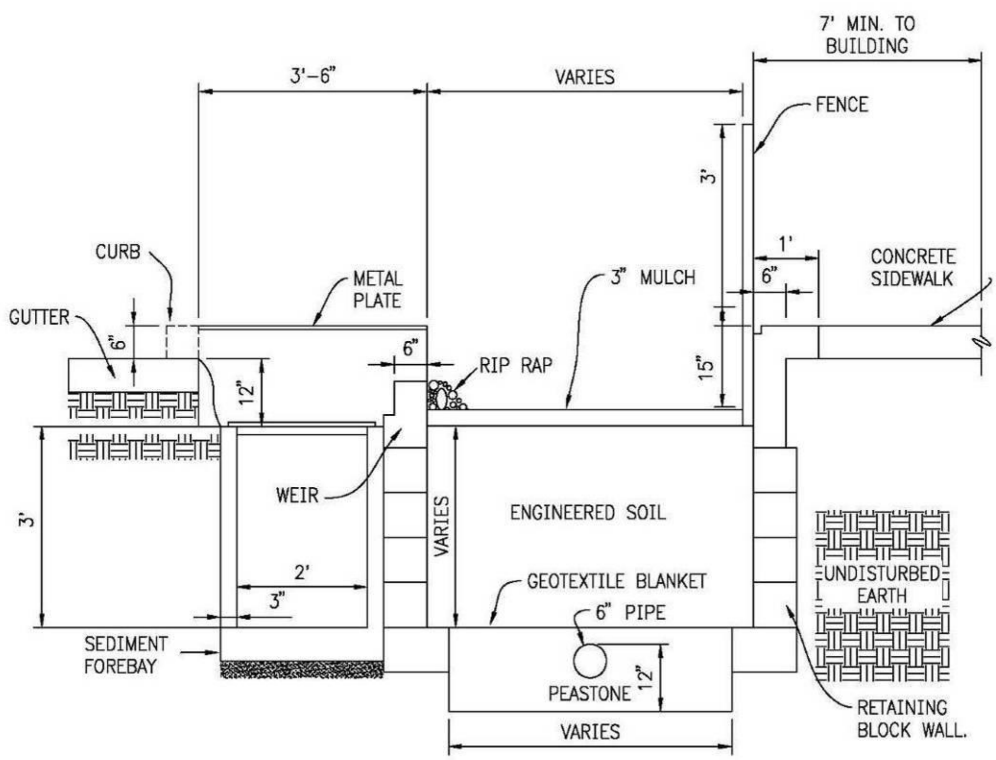


SECTION B-B
CURB EXTENSION PROFILE

Urban Street Bioretention Details

(City of Lansing, Michigan)





7.2 Bioswale

Description

A bioswale is a modified swale that uses bioretention media to improve water quality, reduce the runoff volume, and modulate the peak runoff rate while also providing conveyance of excess runoff.

Bioswale at The Shops at Fallen Timbers in Maumee, Ohio

Benefits and Limitations

- Uses biological, chemical, and physical processes to remove a variety of pollutants
- Able to attenuate flow, reduce volume
- Good retrofit capability
- Provides stormwater treatment and conveyance
- Can be part of infrastructure within transportation rights-of-way
- Can be a landscape feature
- Check dams, weirs, or stepped cells need to be used in areas with steep slopes

Suitable Applications

Bioswales are well suited for use within the rights-of-way of linear transportation corridors. They perform the same functions as grassed swales by serving as a conveyance structure and filtering and infiltrating runoff, but because bioretention media is used, they provide enhanced infiltration, water retention, and pollutant removal.

Runoff reduction is achieved by infiltration and retention in the soils and interception, uptake, and evapotranspiration by the plants. Removal of pollutants has been positively linked to the length of time that the stormwater remains in contact with the herbaceous materials and soils (Colwell, 2000). Bioswales may be used in conjunction with pretreatment BMPs such as filter strips, vegetated filters, or other sediment capturing devices to prevent sediments from accumulating in the swale. The enhanced properties of bioswales do not preclude the need for discharge to another BMP such as a bioretention cell or a detention basin for a large storm event.

Required Design Data

- Stormwater quality and quantity design criteria
- Site characteristics
- Drainage area
- Native soil infiltration rate

Design Guidelines

Location and Siting

- The impervious drainage area to the bioswale should be 0.5 acres or less. Multiple bioswales can be used to treat larger drainage areas.
- Slopes immediately adjacent to the bioswale should be a maximum of 5 percent to ensure positive drainage and prevent erosion.
- Perform an analysis of the existing soils at the start of the design phase to determine whether an underdrain is needed.
- Applicable to sites with soils of sufficient hydraulic conductivity or suitable outlet for an underdrain system to fully drain the practice in a period of approximately 24 to 48 hours.
- Not applicable where groundwater flow will prevent the bioswale from draining between storm events.
- In locations where groundwater pollution potential is high due to high pollution loads, high groundwater table, or extremely permeable soils, an impermeable liner is required.
- Bioswale locations should be integrated into the site planning process, and aesthetic considerations should be taken into account during siting and design.
- Facility elevations (inlet, outlet, overflow) must be carefully worked out to ensure that the desired runoff flow enters the bioswale with no more than the maximum design depth.
- Adhere to local setbacks from important infrastructure. At a minimum: 2 feet from property lines, 100 feet from wells, 50 feet from septic systems, 25 feet from building foundations.

Regulatory Criteria

The primary treatment volume is limited to the Water Quality volume (WQv) per Ohio EPA.

Physical Specifications

- A minimum of 2 feet of separation is recommended between the water table and the bioretention practice.
- Depth of ponding should be less than 6 inches, but may be up to 12 inches provided ponding will not damage plant materials or nearby structures.
- Designs should include a mechanism to dissipate the energy from the flow entering the facility or provide erosion control. Mechanisms to consider include a riprap or stone apron, multiple inlets, a plunge pool, or a proprietary erosion control device.
- The growing medium can range in depth from 1.5 to 4 feet depending on utility conflicts, budget, plant requirements, condition of native soil, and pollutant removal goals. Studies have shown that growing medium depth and infiltration rate affect pollutant removal (Hunt and Lord, 2006). Consider specifying that the contractor use a ripper or sub-soiler to break up 2 feet of native soil beneath the growing medium to increase treatment, storage, and infiltration capabilities.

Growing medium should be sandy loam, loamy sand, or loam texture with a clay content ranging from 10 to 25 percent. The soil should have an infiltration rate of at least 0.5 inches per hour and a pH between 5.5 and 6.5. In addition, the growing medium should have a 1.5 to 3 percent organic content and a maximum 500 ppm concentration of soluble salts.

- The underdrain collection system, if deemed necessary, is a 6 to 8-inch perforated pipe (typically with a sock) in a gravel layer. The depth of the gravel layer depends on the desired storage capacity but is typically at least 12 inches. If root growth is expected, PVC pipe is recommended so that a rooter can be used to clear the pipe.
- Use a gradation of stone or a permeable filter fabric to separate the soil layer from the subsurface gravel layer.
- Two to three inches of fine shredded hardwood mulch should be placed around plants and over soil.
- Native and non-invasive plant species are the best for the overall effectiveness of the practice. Alternatively, grass, trees and shrubs may be used. An erosion control blanket should be specified at construction to prevent washout of plants during establishment.
- On sites with clay soils or compacted soils, the bioswale can be designed with a subsurface storage layer sized to store the water quality volume from its contributing drainage area. Clay soils infiltrate at a rate of about 0.05 inches per hour which is just over 1 inch over a 24-hour period. In combination with subsurface storage or as an alternative, an underdrain could be used as an outlet.
- If the bioswale is to be sloped greater than 2 percent, a series of check dams should be used to promote infiltration and prevent erosion. Designing a bioswale with a slope greater than 5 percent is not recommended.
- Salt tolerant vegetation should be used where road salt is used for de-icing.

Large Storm Conveyance

As with conventional swales, bioswales should be designed with sufficient sidewall depth to safely convey the ten-year design storm without out-of-bank flow.

Pretreatment

Install pretreatment such as a grass filter strip, sediment forebay, or grass channel upstream of the swale.

Operation and Maintenance

The primary maintenance requirement for bioswales is to inspect the treatment area's components and repair or replace them if necessary. Generally, maintenance is the same as the routine periodic maintenance that is required of any landscaped area.

Table 7-2 Bioswale: Typical Maintenance

Activity	Schedule
• Water plants as necessary during plant establishment • Prune and weed plants and remove and replace unsuccessful or diseased plants • Remove trash and debris • Mulch replacement and/or seeding when erosion is evident	As needed
• Remove accumulated sediment and debris from the bioswale and its control structures	Semi-annually
• Replenish the mulch layer to maintain design depth • Stabilize any eroded areas within or that drain to the bioswale	Annually

Depending on the season and type of vegetation, irrigation may be needed during plant establishment. These factors will also determine the irrigation frequency. “Established” means that the soil cover has been maintained for at least one year since replanting. Native plants may require less irrigation than non-natives. In periods of extended drought, temporary supplemental irrigation may be used to maintain plant vitality.

Example Applications

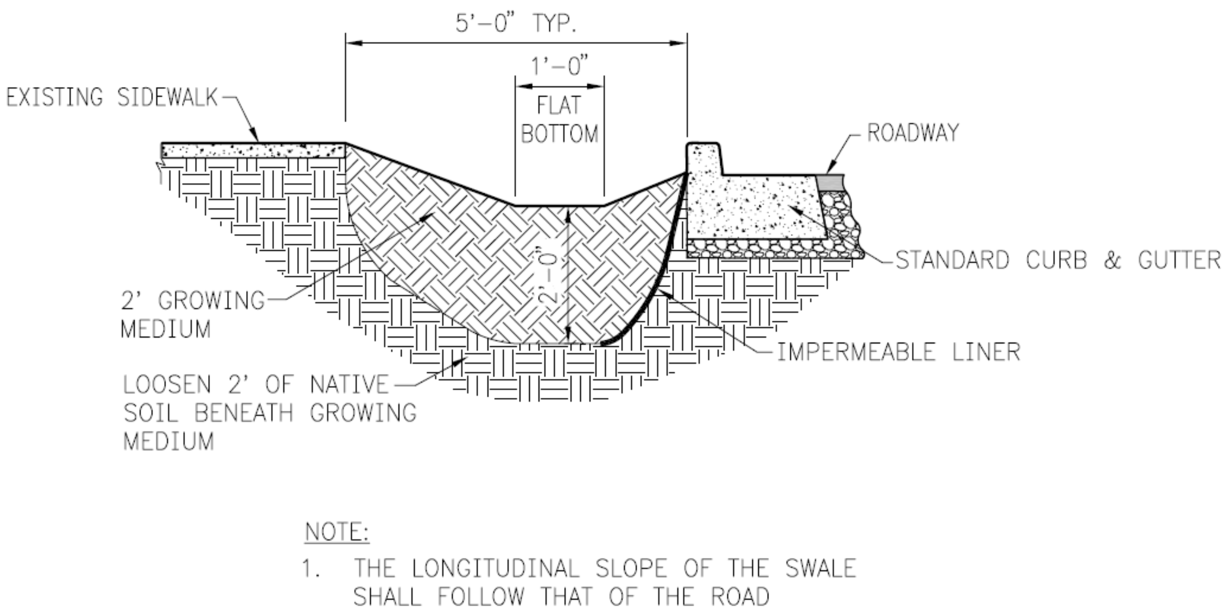
Residential Bioswale

Parking Lot Bioswale

Example Design Details

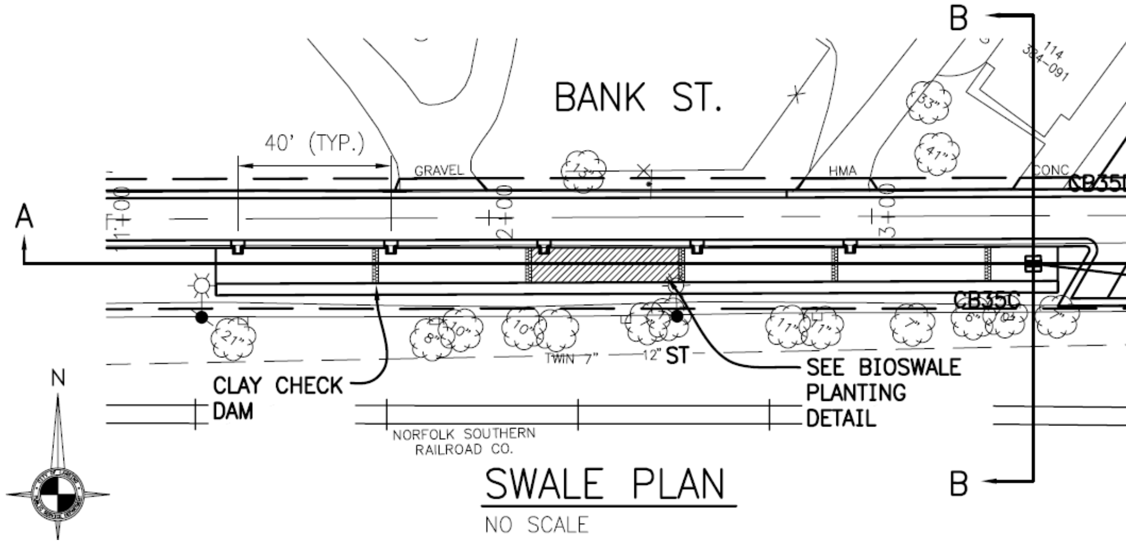
Residential Street Bioswale Cross Section

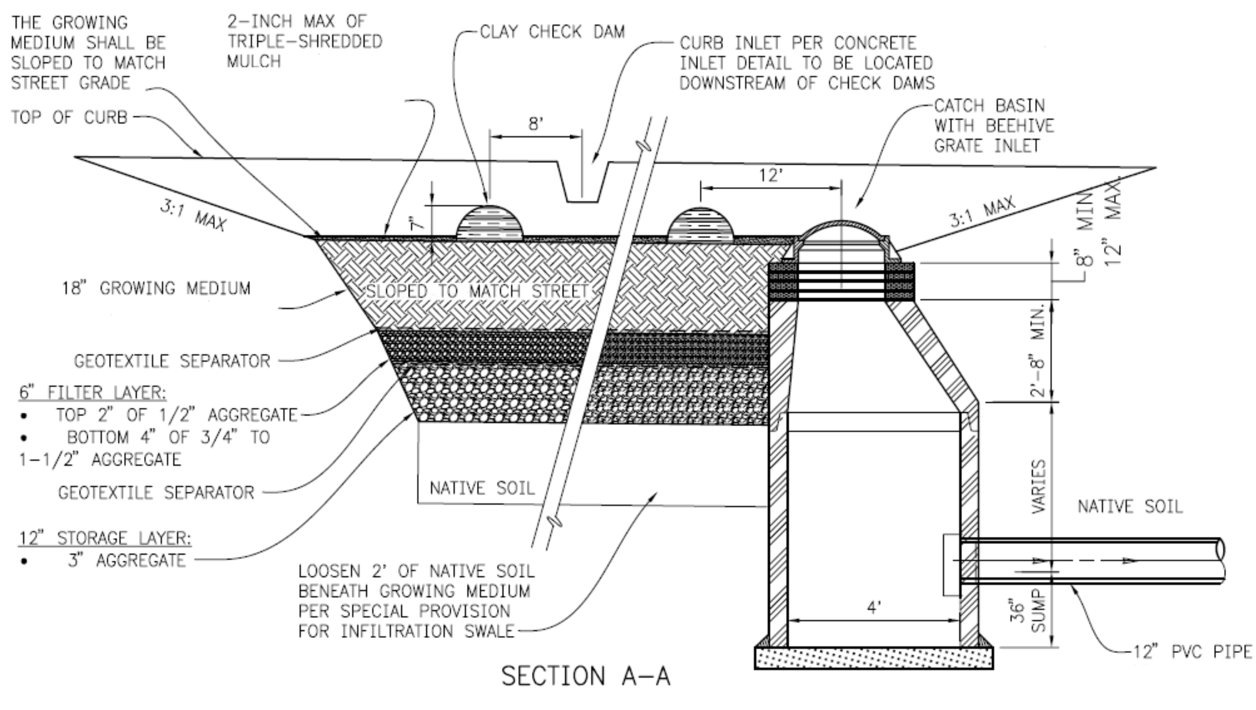
(City of Lansing, Michigan)

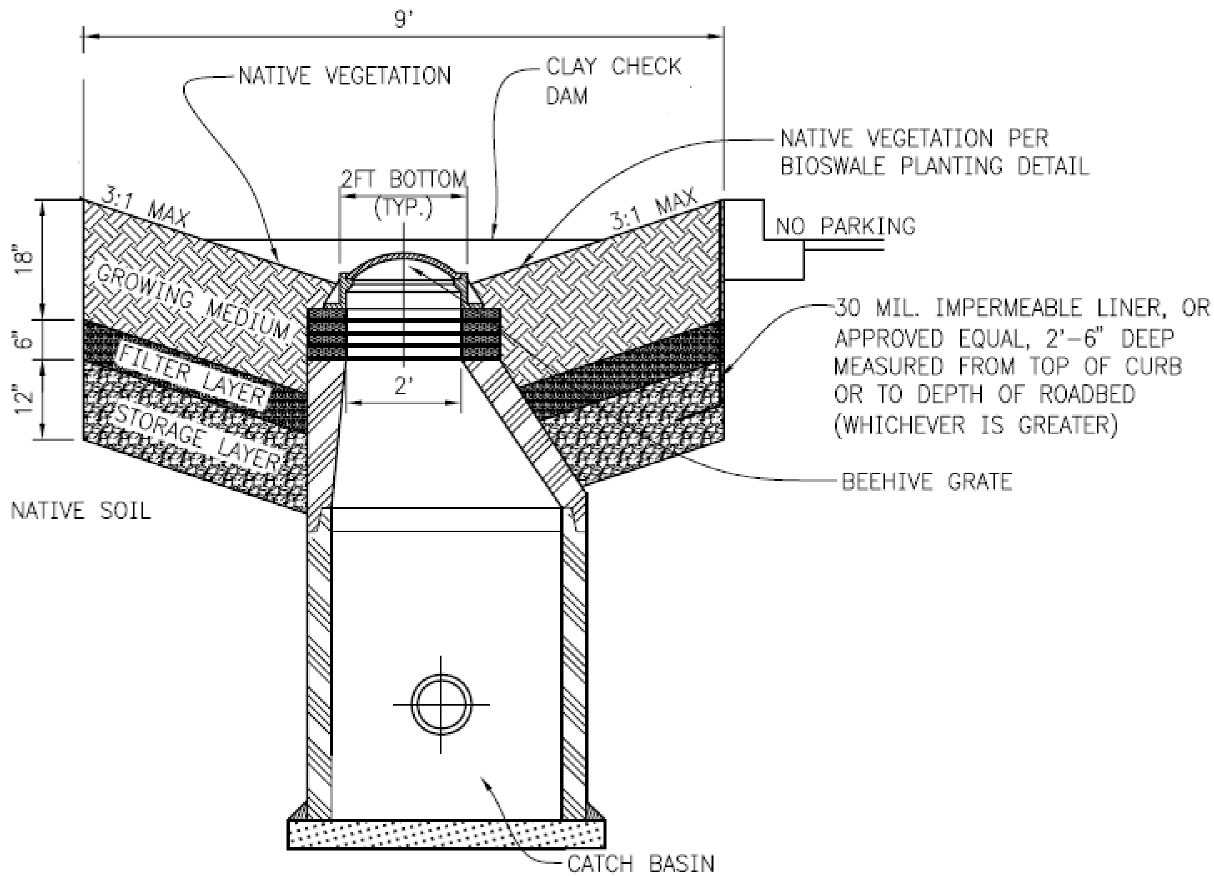


Residential Street Bioswale with Overflow

(City of Lansing, Michigan)





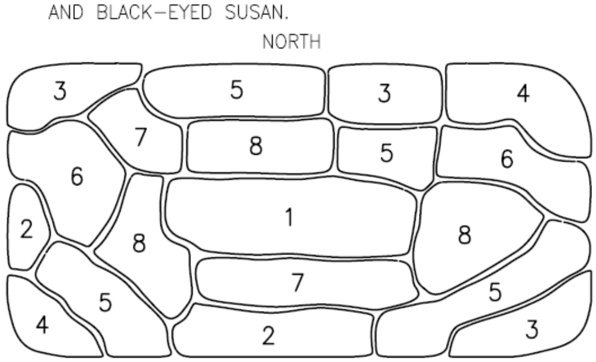


SECTION B-B

BIOSWALE PLANTING DETAIL

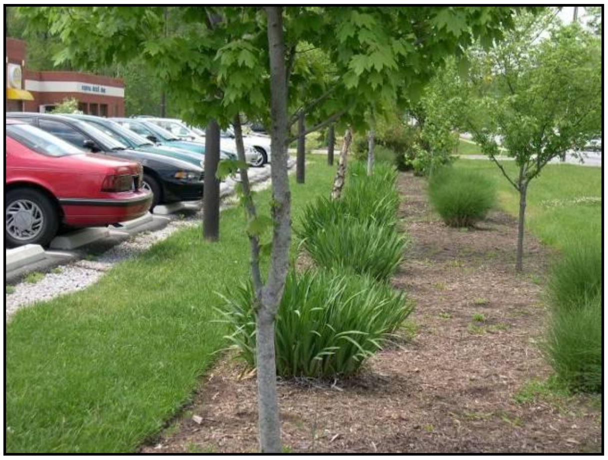
NO SCALE ALL PLUGS. QUANTITIES ARE FOR ENTIRE SWALE OR BERM. PLANT PLUGS ONE FOOT ON CENTER.

NOTE: REPEAT PATTERN 5 TIMES ALONG LENGTH OF SWALE; ONCE BETWEEN EACH CLAY CHECK DAM. PLANT A MIXTURE OF THE SPECIES AROUND CATCH BASIN. PLANT BERM IN CLUMPS OF SWITCH GRASS AND BLACK-EYED SUSAN.



		SWALE
1.	SWITCH GRASS (PANICUM VIRGATUM)	209 SF
2.	CULVER ROOT (VERONICASTRUM VIRGINICUM)	139 SF
3.	BLACK-EYED SUSAN (RUDBECKIA HIRTA)	219 SF
4.	LITTLE BLUESTEM (SCHIZACHYRIUM SCOPARIUM)	159 SF
5.	BLAZING STAR (LIATRIS SPICATA)	370 SF
6.	PURPLE CONEFLOWER (ECHINACEA PURPUREA)	202 SF
7.	MISSOURI IRONWEED (VERNONIA MISSURICA)	171 SF
8.	BLUE FLAG IRIS (IRIS VERSICOLOR)	294 SF

7.3 Filter Strip



Grass filter strip as a pretreatment to an infiltration area

Description

Filter strips are bands of dense, permanent vegetation with a uniform slope, primarily designed to provide water quality pretreatment between a runoff source (i.e., impervious area) and another BMP.

Benefits and Limitations

- Uses vegetative filtering and infiltration to remove pollutants
- Able to attenuate flow and reduce volume if soils are sufficiently permeable
- Prevents sediments and other materials from reaching and clogging downstream BMPs
- Effectiveness governed by runoff contact time and density of vegetation
- A permeable berm may be installed on the downstream end to increase stormwater contact time and contain the water quality volume

Suitable Applications

Filter strips are well suited for treating runoff from roads, parking lots, and disconnected downspouts. They may also be used along streams to treat agricultural runoff and may be referred to as buffer strips. They are intended to treat sheet flow from adjacent areas and can be effective at removing sediments and other pollutants. Because of their ability to decrease sediment loads, filter strips often serve as pretreatment for other BMPs such as infiltration trenches or bioretention.

Filter strips provide water quality improvement primarily through vegetative filtering and infiltration. Reductions in runoff volume from small storms can be achieved if the soils are sufficiently pervious, sheet flow is maintained along the entire length and width of the strip, and contact time is long enough for infiltration to occur.

Required Design Data

- Stormwater quality and quantity design criteria
- Site characteristics
- Length of flow path from contributing drainage area
- Drainage area

- Native soil infiltration rate

Design Guidelines

Location and Siting

- Filter strips are typically used to treat drainage from a relatively small impervious area.
- The length of the flow contributing to the filter strip is the primary design factor. Limiting flow length to 100 feet or less will maintain sheet flow and prevent the concentration and channelization of runoff. Channelized flow moves too rapidly and along too narrow a path to be treated effectively.
- The slope of a filter strip should be between 2 and 5 percent to prevent runoff ponding or channelization.
- Perform an analysis of the existing soils at the start of the design phase to determine infiltration rate.
- If soil is high in clay content, infiltration rates can be improved by amending the soil with a bulking agent such as coir fiber (coconut fiber) or mulch, aged 12 months. Soils unsuitable for sustaining healthy, dense, vegetative cover should be avoided.

Regulatory Criteria

- The primary treatment volume used for the design and sizing of filter strips is the Water Quality volume (WQv) per Ohio EPA.

Physical Specifications

- A minimum of 2 feet of separation is recommended between the water table and the bioretention practice.
- A pervious berm of sand and gravel at the toe of the slope can be installed to allow for the shallow ponding of the WQv. The permeable berm allows for temporary stormwater ponding and adequate treatment time.
- The width of the filter strip should be at least the same width as the area to be treated. Wider filter strips are more effective.
- Selected grasses or vegetation should be able to withstand stormwater flows and sustain through wet and dry periods.
- The toe and top of the slope should be as flat as possible to encourage sheet flow and prevent erosion.
- Salt tolerant vegetation should be used where road salt is used for de-icing.

Pretreatment

A gravel diaphragm (a trench at the top of the filter strip) can be used to settle sediment before it reaches the filter strip and to act as a level spreader by maintaining sheet flow as runoff flows over the filter strip.

Operation and Maintenance

The primary maintenance requirement for filter strips is mowing and inspecting for erosion. Maintenance is similar to other vegetated areas.

Table 7-3 Filter Strip: Typical Maintenance

Activity	Schedule
• Water vegetation as necessary during establishment period • Mow grass to 3 or 4 inches in height	As needed
• Inspect and remove accumulated sediment from gravel diaphragm • Inspect filter strip for rill and gullies. Reseed or re-sod as needed	Annually
• Remove accumulated sediment at the bottom of the filter strip	Every 2 to 3 years

Depending on the season and type of vegetation, irrigation may be needed during plant establishment. These factors will also determine the irrigation frequency. “Established” means that the soil cover has been maintained for at least one year since replanting. Native plants may require less irrigation than non-natives. In periods of extended drought, temporary supplemental irrigation may be used to maintain plant vitality.

Example Applications

Courtesy of Mercer County, Ohio

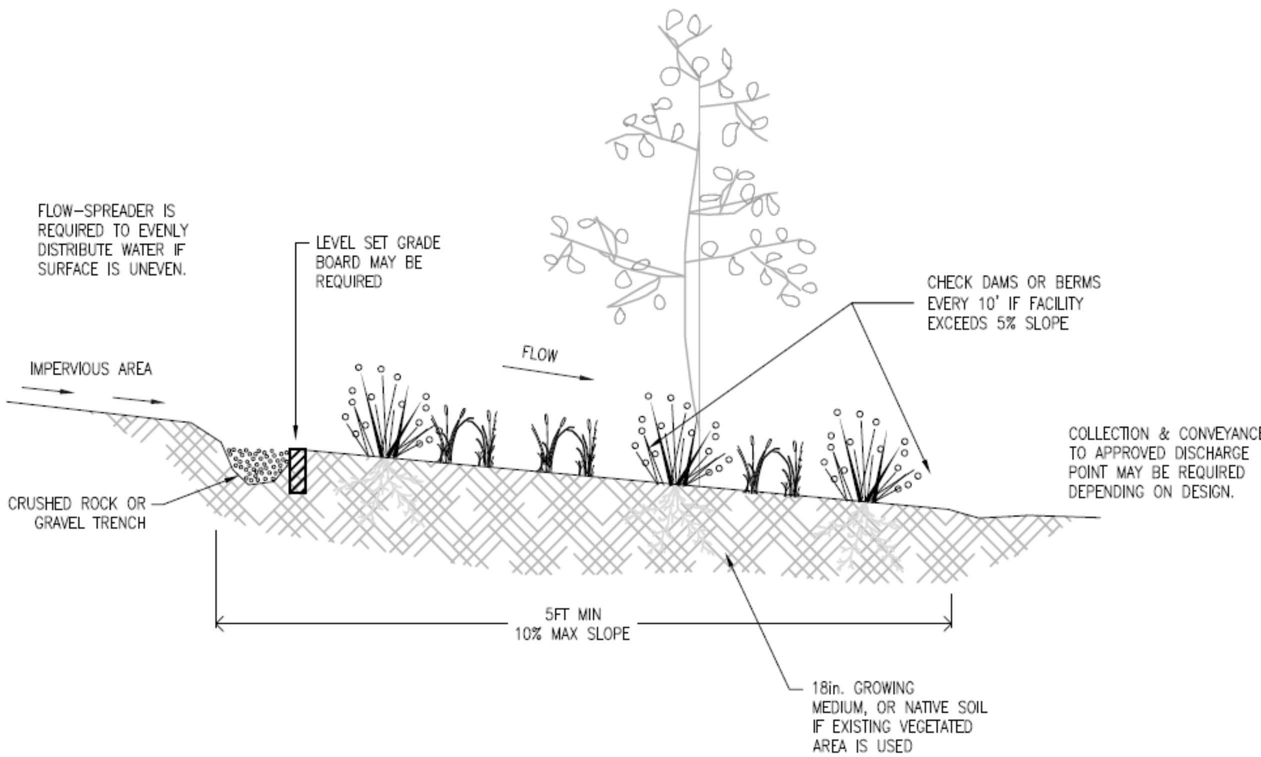
Filter strip adjacent to agricultural field

Gravel diaphragm upstream of grass filter

Example Design Details

Filter Strip

(City of Portland, Oregon)



References

Portland, City of, Bureau of Environmental Services. (2008). *Stormwater Management Manual.* Web Site last accessed December 31, 2009. www.portlandonline.com/BES/index.cfm?c=47952

U.S. Environmental Protection Agency. *Stormwater Management Fact Sheet: Grassed Filter Strip*, Office of Wastewater Management – Stormwater Manager's Resource Center.

7.4 Permeable Paving

Pervious asphalt

Description

Permeable pavements contain small voids that allow stormwater to drain through the pavement to an aggregate reservoir and then infiltrate into the soil. They may be a modular paving system (concrete pavers, grass-pave, or gravel-pave) or poured in place solutions (pervious concrete, pervious asphalt).

Benefits and Limitations

- Alternative to impervious hardscapes
- Reduces the impervious area of a site
- Uses biological, chemical, and physical processes to remove a variety of pollutants
- Able to attenuate flow and reduce volume
- Pavement layer and aggregate subbase provide rapid infiltration; total volume retention will be dependent upon properties of native soils
- Used to manage rain that falls on the surface rather than "run-on" from other areas

Suitable Applications

Permeable pavement is typically used to replace traditional impervious pavement for most pedestrian and vehicular applications except high-volume/high-speed roadways. Permeable pavements have been used successfully in pedestrian walkways, sidewalks, driveways, parking lots, and low-volume roadways. Several design options are available for using permeable pavements to intercept, contain, filter, and infiltrate stormwater on site. Permeable pavements can be installed across an entire street width or an entire parking area. Alternatively, they can be installed in combination with impermeable pavements to infiltrate runoff; several applications use permeable pavement in parking lot lanes or parking stalls to treat runoff from adjacent impermeable pavements.

Permeable pavements are used to reduce the volume of stormwater runoff by converting an impervious area to a treatment unit. The aggregate subbase provides water quality improvements through filtering and chemical and biological processes. The volume reduction and water treatment capabilities of permeable pavements are effective at reducing pollutant loads.

Required Design Data

- Stormwater quality and quantity design criteria
- Site characteristics
- Native soil infiltration rate

Design Guidelines

Location and Siting

- Permeable pavements are most often used in parking areas, low volume/low speed roadways, pedestrian areas, and driveways.
- Permeable pavements can be used for the entire paved surface or can be used in dedicated locations such as parking stalls. This can economize installation costs while in many instances providing sufficient treatment area for the runoff generated from impervious surfaces.
- For slopes greater than 2 percent, terracing of the soil subgrade base may likely be needed to slow runoff from flowing through the pavement structure.
- Perform an analysis of the existing soils at the start of the design phase to determine infiltration rate.
- Permeable pavements are not appropriate for stormwater hotspots where hazardous materials are loaded, unloaded, or stored or where there is a potential for spills and fuel leakage.
- The infiltration rate of the soils or an installed underdrain should drain the subbase in 24 to 48 hours.

Regulatory Criteria

The Water Quality volume (WQv) per Ohio EPA is most often used to determine the stormwater volume to be captured, stored, or infiltrated in a permeable pavement system.

Physical Specifications

- Permeable pavements are supported by an aggregate subbase that is typically 1 foot to several feet in depth. If using a permeable paver unit, the manufacturer of the paver typically recommends the gradation of the subbase layers.
- The minimum separation from the bottom of the aggregate subbase to bedrock or to the seasonally high water table is 2 feet.
- In instances where permeable pavements are installed over low-permeability soils, an underdrain should be installed to facilitate water removal from the subbase and pavement. Having an outlet for the water is particularly important when the temperature drops below freezing to protect the pavement.
- The underdrain collection system, if deemed necessary, is a 6- to 8-inch perforated pipe (typically with a sock) in a gravel layer. The depth of the gravel layer depends on the desired storage capacity but is typically at least 12 inches.

- To compensate for the lower structural support capacity of clay soils, additional subbase depth is often required. Added depth also provides additional storage volume to compensate for the lower infiltration rate of the clay.
- An impermeable liner may be installed between the subbase and the native soil to prevent water infiltration when clay soils have a high shrink-swell potential or there is a high water table or bedrock layer.
- A geotextile separator should be considered between the subbase and adjacent soils to prohibit migration of fine soils into the permeable pavement system subbase.
- Consider installing a concrete header between permeable paving and adjacent impermeable paving to help keep the permeable paving in place and to create a clean edge.

Emergency Spillway

Storm sewer inlets can be installed in permeable pavements to accommodate overflows from extreme storms.

Pretreatment

Measures should be taken to protect permeable pavements from high sediment loads, particularly fine sediment. Appropriate pretreatment BMPs for run-on to pavement include filter strips and swales.

Operation and Maintenance

The primary maintenance requirement for permeable pavement is inspecting the pavement materials for damage and repairing as necessary.

Table 7-4 Permeable Pavement: Typical Maintenance

Activity	Schedule
• Remove accumulated sediment and particulates from the permeable pavement void spaces with high efficiency vacuum sweepers	Annually

Example Applications

Cellular paver blocks with grass

Porous asphalt parking lot

Porous concrete parking lot

Permeable paver block parking lot

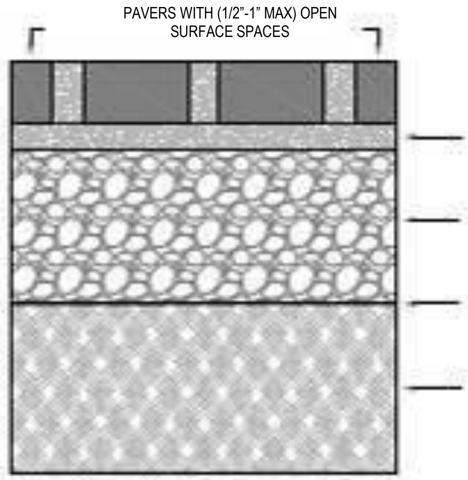
Permeable paver block parking lane

Permeable paver block parking lot (stalls only)

Example Design Details

Pervious Pavement

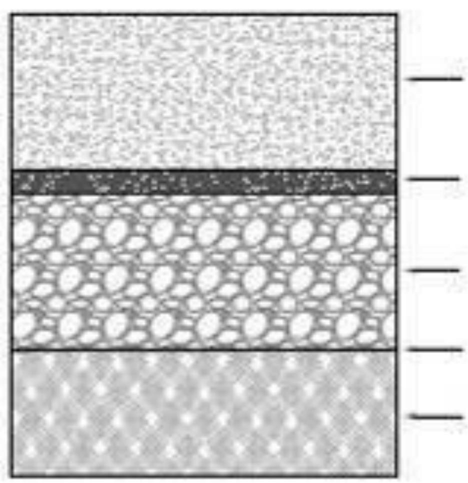
(City of Portland, Oregon)



PERMEABLE CONCRETE BLOCK OR "PAVER" SYSTEMS

	RESIDENTIAL DRIVEWAY OR PEDESTRIAN	PRIVATE STREET, PARKING LOT, OR FIRE LANE	PUBLIC STREET
CONCRETE	4"	4"	7"
ASPHALT	2 1/2"	3"	6"
PAVERS	2 3/8"	3 1/8"	3 1/8"
ENGINEERING REQUIRED	NO	YES	YES
COMPACTION REQUIRED	NO	YES	95%

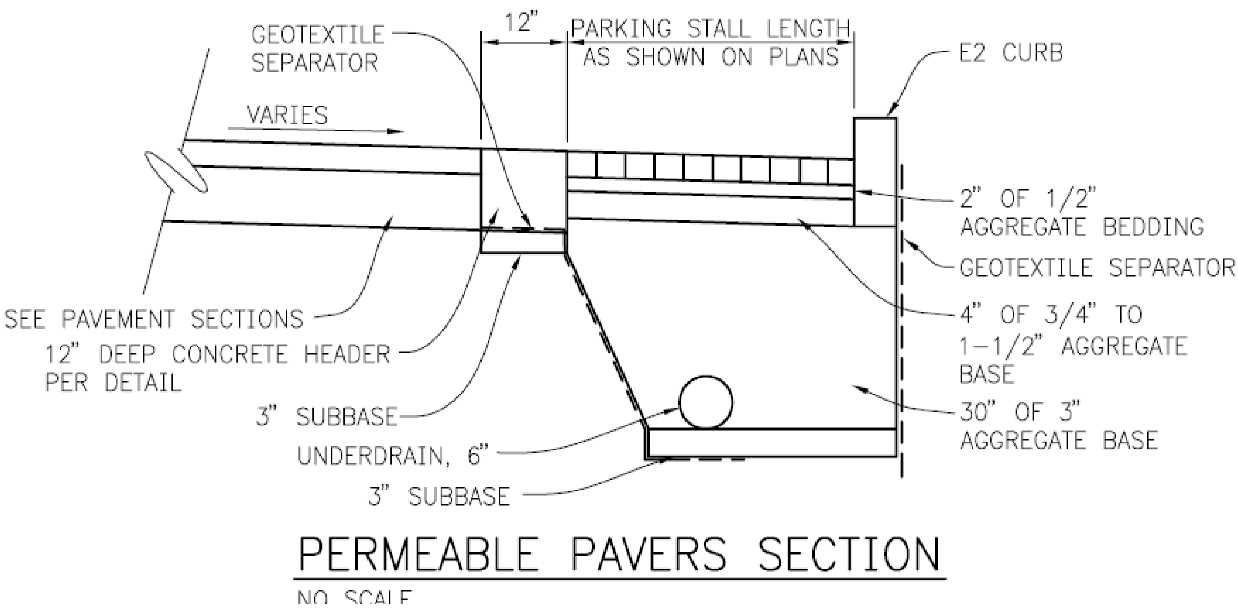
PERVIOUS PAVEMENT REQUIREMENTS FOR TOP LIFT DEPTH, ENGINEERING AND COMPACTION



PERMEABLE (OPEN GRADED) CONCRETE AND ASPHALT SYSTEMS

Paver Blocks in Parking Lane

(City of Lansing, Michigan)



References

Hunt, W.F. and K.A. Collins. (2008). *Permeable Pavement: Research Update and Design Implications*, North Carolina State University Cooperative Extension, Raleigh, NC. Publication # AGW-588-14.

Portland, City of, Bureau of Environmental Services. (2008). *Stormwater Management Manual.* Web Site last accessed December 31, 2009. www.portlandonline.com/BES/index.cfm?c=47952

7.5 Tree Box

Tree box

Description

Tree boxes are urban applications of high-rate bioretention systems with vegetation and bioretention media contained in a pre-cast concrete box designed to install like a standard curb inlet.

Benefits and Limitations

- Uses biological, chemical, and physical processes to remove a variety of pollutants
- Able to attenuate peak flow rates
- Good retrofit option to use with existing infrastructure
- Can be used for streetscaping
- Primarily a water quality device with limited volume retention

Suitable Applications

Tree boxes are used to intercept and filter stormwater as it enters the conventional stormwater conveyance system. Installed upstream of a standard curb inlet, tree boxes appear to be a tree or other vegetation in a tree grate along a curb. The vegetation sits in a box of bioretention media through which street or parking lot runoff is filtered prior to entering the collection system.

For low to moderate flows, stormwater enters through the tree box inlet, filters through the soil, and exits through an underdrain into the storm drain. For high flows, stormwater will bypass the tree box if it is full and flow directly to the downstream curb inlet. Small trees and shrubs up to 15 or 20 feet that are tolerant of tree box conditions are suitable vegetation choices. Typically tree boxes are 6 feet by 6 feet and treat runoff from a ¼ acre of impervious surface. Larger and smaller sized tree boxes are available including double tree boxes that may accommodate canopy trees.

Required Design Data

- Stormwater quality design criteria
- Drainage area

Design Guidelines

Location and Siting

- Tree boxes are installed immediately upstream of a standard stormwater inlet to allow the underdrain to tie into the existing infrastructure and allow excess flows that bypass the tree box to enter the collection system.
- The drainage area for a typical 6 foot by 6 foot tree box is ¼ acre of impervious surface. A series of tree boxes used along a street or larger sized tree boxes can be used for larger drainage areas.
- They are used primarily for retrofits to provide water quality improvements prior to the stormwater entering the collection system.
- Facility elevations (inlet, underdrain) must ensure positive discharge to the collection system.
- Tree boxes should be regularly spaced along the length of a transportation corridor or parking lot as appropriate to meet the annual treatment target.

Regulatory Criteria

Tree boxes can be sized, situated, and located to provide treatment for the Water Quality volume (WQv) of runoff per Ohio EPA.

Physical Specifications

- Tree boxes are off-line devices and should not be placed in a sump position.
- Tree boxes should be installed to allow runoff to flow across the inlet.
- Tree boxes are intended for intermittent flows and not intended as larger event detention devices.

Emergency Spillway

Tree boxes are designed to allow stormwater flows in excess of the unit's capacity to bypass the tree box and flow directly into the adjacent stormwater inlet.

Pretreatment

Designed to be rapid infiltration water quality devices, pretreatment is typically not used for tree boxes.

Operation and Maintenance

The primary maintenance requirement for tree boxes is to inspect the vegetation and soil and remove accumulated trash and sediment. Generally, maintenance is the same as the routine periodic maintenance required of any landscaped area.

Table 7-5 Tree Box: Typical Maintenance

Activity	Schedule
• Water plants as necessary during plant establishment • Prune vegetation • Remove trash and debris	As needed
• Remove accumulated sediment and debris	Semi-annually
• Replenish the mulch layer to maintain design depth	Annually

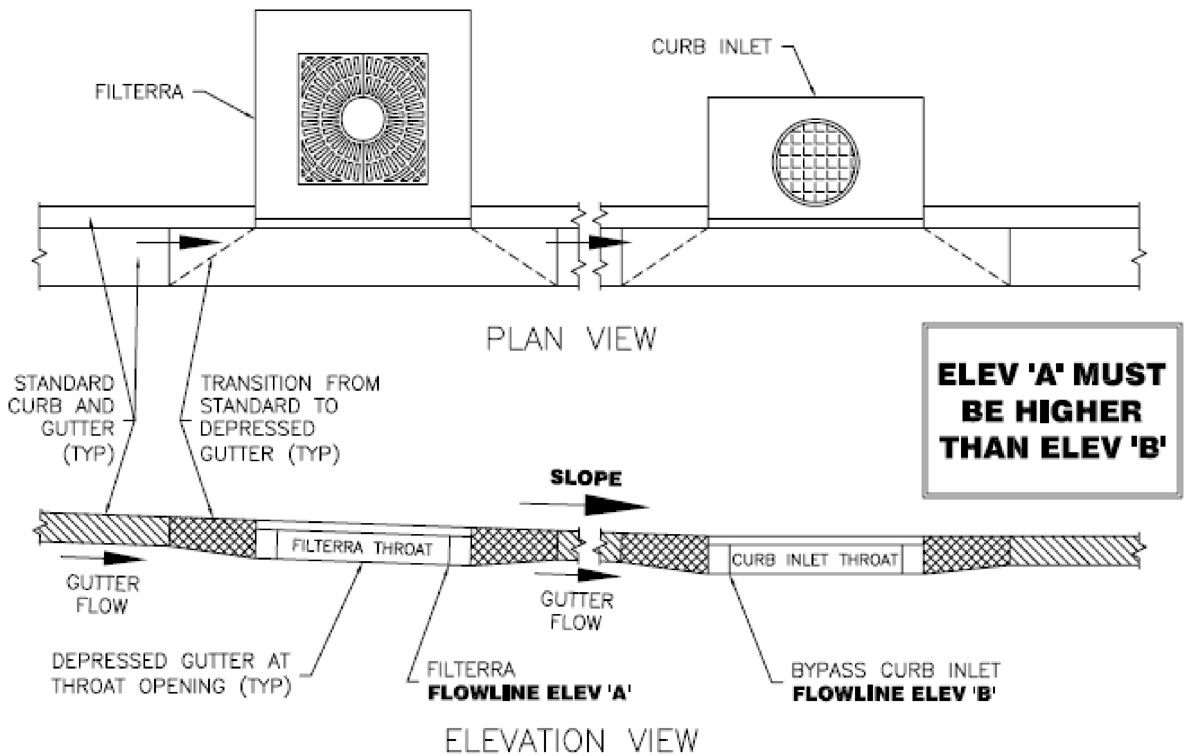
Example Applications

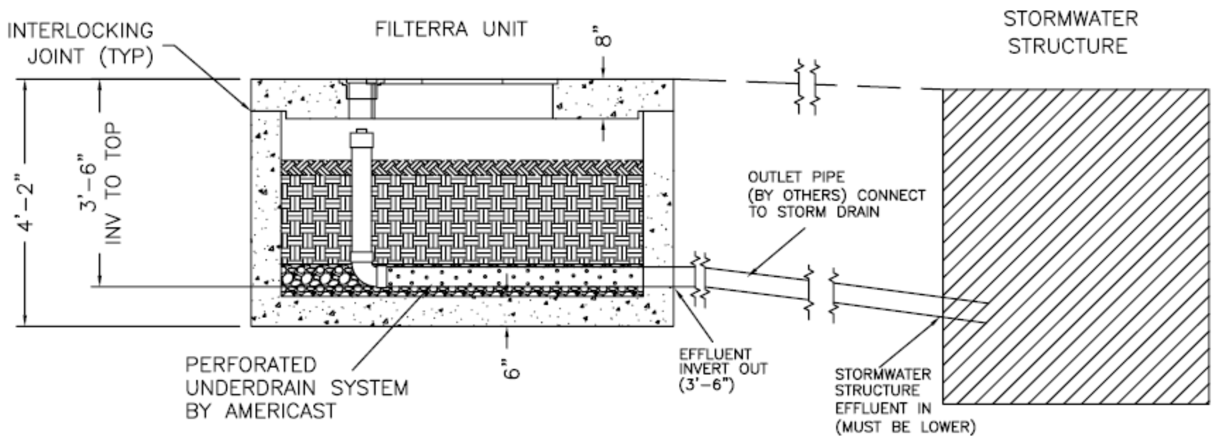
Courtesy of Larry Coffman
Tree box along local street

Example Design Details

Tree Box

(Filterra)





CROSS SECTION

MODIFICATIONS OF DRAWINGS ARE ONLY PERMITTED
BY WRITTEN AUTHORIZATION FROM FILTERRA

7.6 Infiltration Trench

Infiltration trench

Description

An infiltration trench is an excavated trench lined with filter fabric and backfilled with stone to allow stormwater to infiltrate into subsurface soils.

Benefits and Limitations

- Uses biological, chemical, and physical processes to remove a variety of pollutants
- Able to attenuate flow, reduce volume
- Useful for space limited applications
- Can be used within transportation rights-of-way
- Need appropriate pretreatment for optimal effectiveness
- May need to register as a Class V well with the Ohio EPA (per federal regulation 40 CFR §144.83)

Suitable Applications

Infiltration trenches are well suited for roadway medians and shoulders and applications with limited available space. They allow the volume of stormwater discharges to be reduced by promoting infiltration and allowing runoff to percolate into native soils through the sides and bottom of the trench.

Infiltration trenches are designed to reduce the volume of runoff while providing water quality improvements through pollutant removal mechanisms such as filtration, sorption, and chemical and biological degradation. They also allow for groundwater recharge. Infiltration trenches must be used in conjunction with pretreatment BMPs such as filter strips or other sediment capturing devices to prevent sediments from clogging the trench.

Required Design Data

- Stormwater quality and quantity design criteria
- Site characteristics
- Drainage area
- Native soil infiltration rate

Design Guidelines

Location and Siting

- The impervious drainage area to the infiltration trench should be 2 acres or less.
- Slopes immediately adjacent to the infiltration trench should be between a maximum of 5 percent to ensure positive drainage and prevent erosion.
- Perform an analysis of the existing soils at the start of the design phase in order to determine whether an underdrain is needed.
- Applicable to sites with soils of sufficient hydraulic conductivity or suitable outlet for an underdrain system to fully drain the practice in a period of approximately 24 to 48 hours.
- Not applicable where groundwater flow will prevent the infiltration trench from draining between storm events.
- Not suitable for locations where groundwater pollution potential is high due to high pollution loads or high groundwater table.
- Adhere to local setbacks from important infrastructure. At a minimum: 2 feet from property lines, 100 feet from wells, 50 feet from septic systems, 25 feet from building foundations.

Regulatory Criteria

The Water Quality volume (WQv) per Ohio EPA is commonly used as the minimum basis for sizing an infiltration trench.

Physical Specifications

- The minimum of 2 feet of separation is recommended between the water table and the infiltration trench.
- Locate the infiltration trench at least 5 feet down-gradient from the edge of the roadway or use an impermeable liner to prevent the water from migrating beneath the pavement.
- On sites with clay soils or compacted soils, the infiltration trench can be designed with subsurface storage sized to store the water quality volume from its contributing drainage area. The ponding depth should be restricted to a depth that will drain below the soil surface in approximately 24 hours based on the infiltration rate of the existing soil, which should be measured at the location of the trench with a double-ring infiltrometer or other approved method of testing. Clay soils infiltrate at a rate of about 0.05 inches per hour which is just over 1 inch over a 24-hour period. In combination with subsurface storage or as an alternative, an underdrain could be used as an outlet. In low-permeability soils where infiltration is relied upon for the outlet, it is particularly important to include an effective sediment removal mechanism so as not to plug the subsurface storage layer or underlying existing soils.
- The underdrain collection system, if deemed necessary, is a 6- to 8-inch perforated pipe (typically with a sock) in a gravel layer. The depth of the gravel layer depends on the

desired storage capacity but is typically at least 12 inches. If root growth is expected, PVC pipe is recommended so that a rooter can be used to clear the pipe.

- A permeable filter fabric is used to separate the native soils from the stone in the trench.

Large Storm Conveyance

In addition to treating the WQv of runoff, infiltration trenches are typically sized to allow for treatment of the 10-year design storm.

Pretreatment

- Pretreatment is required for infiltration trenches to remove sediments, prevent clogging, and allow for expected performance.
- Filter strips are commonly used for pretreatment but must be sufficiently wide to reduce runoff velocity and trap sediment. A pea gravel apron can also be used for pretreatment prior to the infiltration trench.

Operation and Maintenance

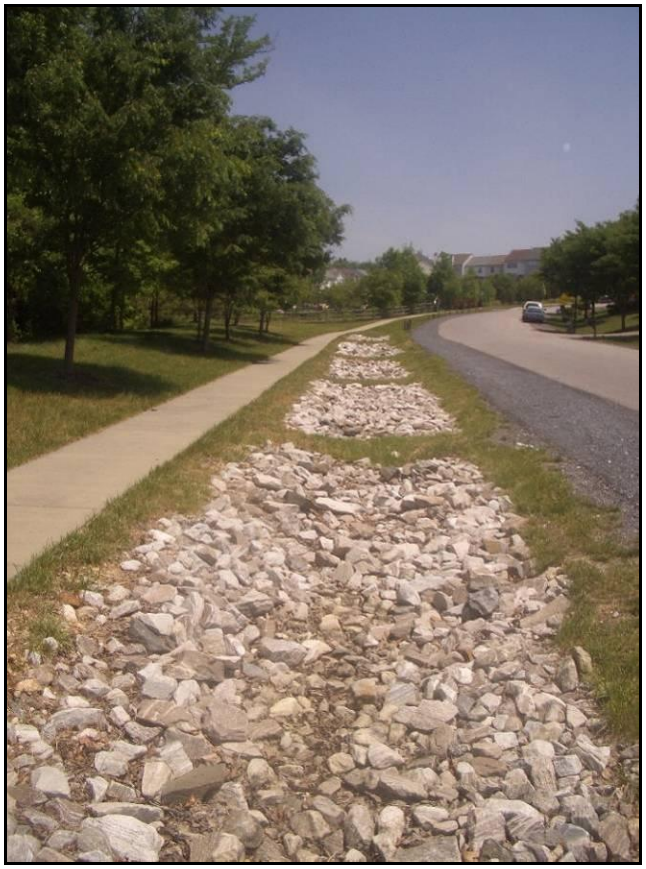
The primary maintenance requirement for infiltration trenches is to inspect them for sediment and debris accumulation. It is also necessary to inspect the pretreatment device and conduct repairs if necessary.

Table 7-6 Infiltration Trench: Typical Maintenance

Activity	Schedule
• Inspect pretreatment area and trench and remove accumulated sediment and debris • Stabilize any eroded areas in pretreatment area	Annually

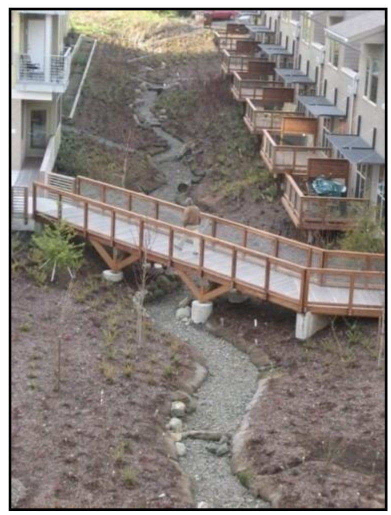
If vegetation is used, irrigation may be needed during plant establishment. These factors will also determine the irrigation frequency. “Established” means that the soil cover has been maintained for at least one year since replanting. Native plants may require less irrigation than non-natives. In periods of extended drought, temporary supplemental irrigation may be used to maintain plant vitality.

Example Applications



Courtesy of Lake County, Illinois
Stormwater Management Commission
Infiltration trench along roadway shoulder

Courtesy of Wisconsin
Department of Natural Resources
Infiltration trench with grass filter strip adjacent to parking lot

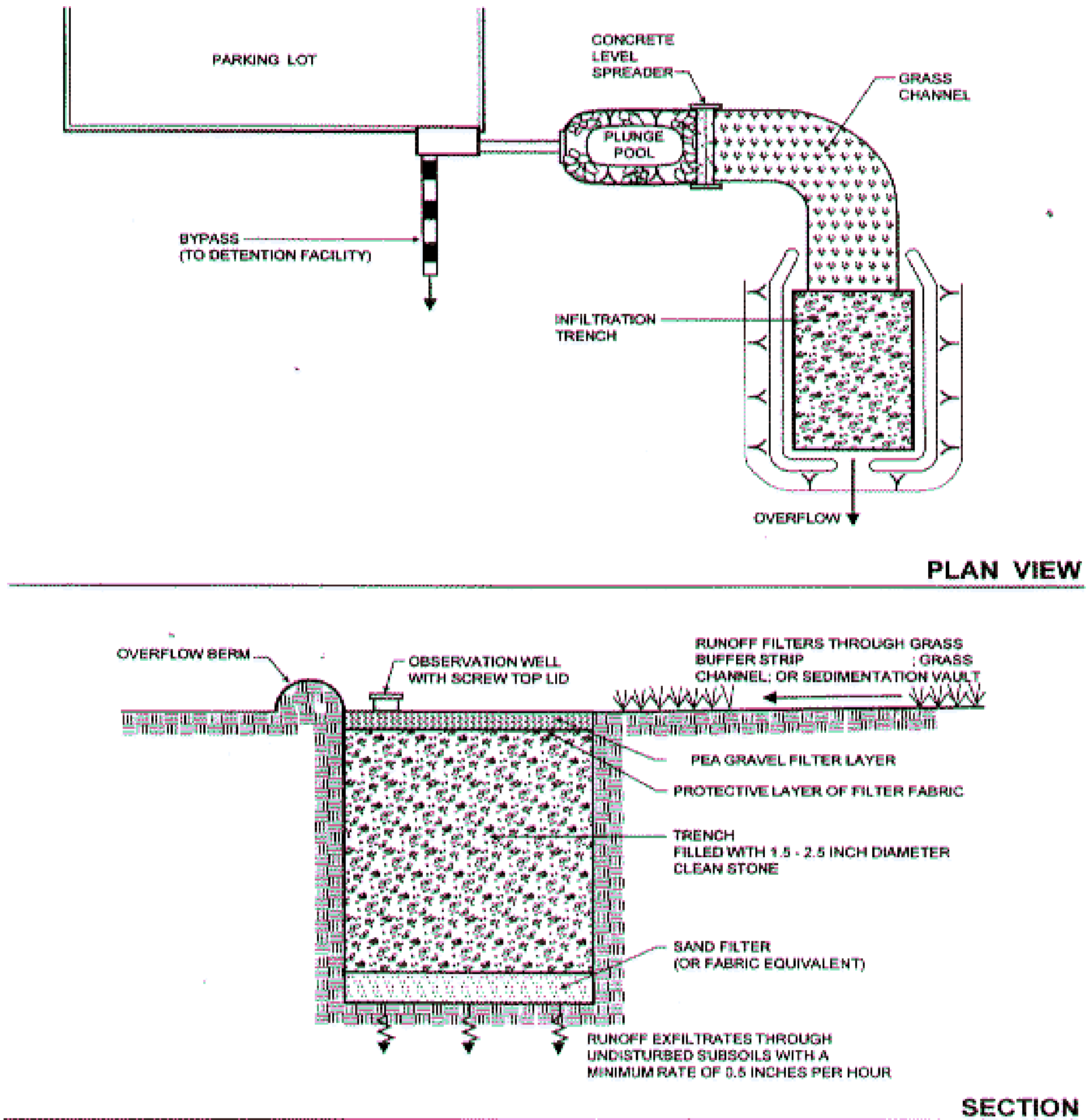


Infiltration trench in housing complex

Example Design Details

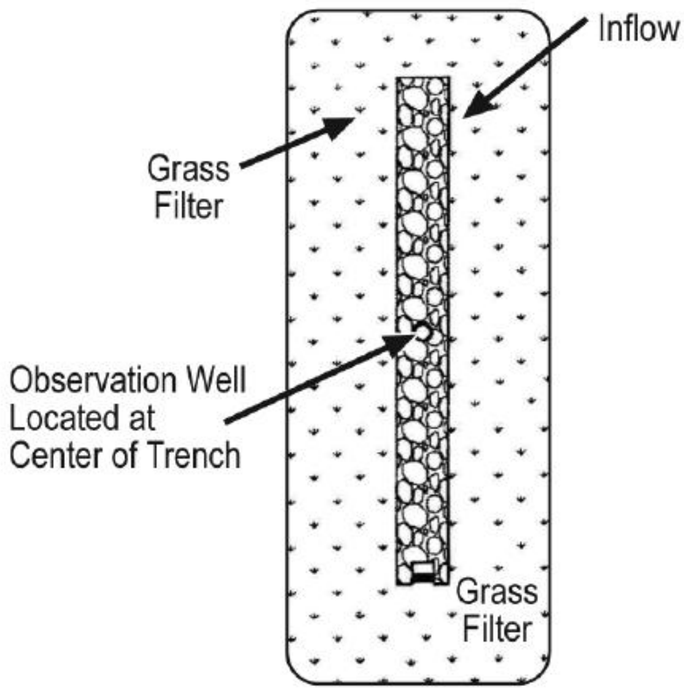
Infiltration Trench

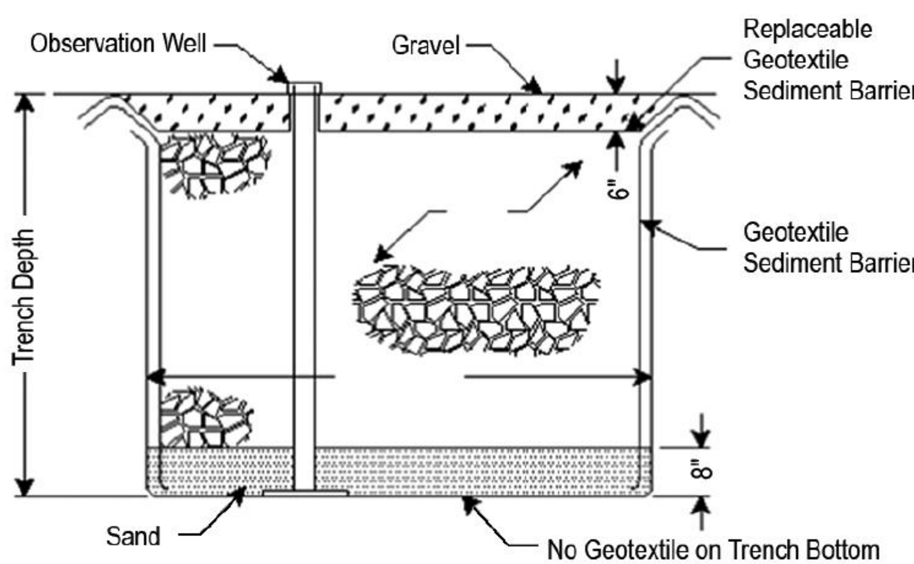
(Stormwater Center)



Infiltration Trench

(Minnesota Stormwater Manual, 2005)





7.7 Stormwater Wetlands

Description

Stormwater wetlands are shallow, man-made vegetated systems designed to provide stormwater detention and pollutant removal.

Stormwater wetland

Benefits and Limitations

- Uses biological, chemical, and physical processes to remove a variety of pollutants
- Can be designed for enhanced nitrogen removal by creating aerobic and anaerobic zones
- Able to attenuate flow
- Reduces runoff temperature
- Creates habitat
- Enhances site aesthetics
- Can require larger parcels of land

Suitable Applications

Stormwater wetlands are constructed shallow marsh systems designed and placed to use the natural processes of wetland vegetation, soils, and their associated biological activity to provide treatment for stormwater runoff. As engineered facilities, stormwater wetlands have less biodiversity than natural wetlands but still require a base flow to support the aquatic vegetation present.

Pollutant removal in these systems occurs through the settling of larger solids and course organic material and also by uptake in the aquatic vegetation. Wetlands can also be designed to remove ammonia through nitrification/denitrification processes, which may be particularly useful in agricultural settings. It is typically appropriate to construct these wetlands in upland regions and outside of floodplains to avoid impacts to natural wetlands and aquatic systems. Stormwater wetlands can be used to enhance the aesthetics of a site and to increase the available habitat.

Required Design Data

- Stormwater quality and quantity design criteria
- Site characteristics
- Drainage area
- Native soil infiltration rate

Design Guidelines

Location and Siting

- Stormwater wetlands are typically designed to treat the runoff from a 5- to 10-acre drainage area.
- Stormwater wetlands should not be sited in natural wetland areas or floodplains.
- Siting should avoid conditions conducive to stagnating water and short circuiting stormwater through the system.
- Designs should avoid the use of rectangular basins, rigid structures, and straight channels. Soft structures, diverse and sinuous edges in design configuration, and practices that incorporate the existing natural landscape and native vegetation should be used.
- Site soils influence the design of wetlands. Highly permeable soils that facilitate infiltration may prevent the development of hydrological conditions suitable to support wetland vegetation.
- Perform an analysis of the existing soils at the start of the design phase in order to determine their suitability for a wetland system. An impermeable liner can be used to improve the suitability of the site if needed.
- Natural wetlands should not be used for stormwater management.

Regulatory Criteria

The primary treatment volume is limited to the Water Quality volume (WQv) per Ohio EPA.

Physical Specifications

- Stormwater wetlands are designed with three distinct zones: a forebay immediately after the inlet to receive stormwater, the wetland area, and a micropool immediately prior to the outfall. The forebay and micropool allow for sediment control.
- Hydraulic detention of stormwater is achieved through an increase in the water depth of the wetland. Detention times are typically 24 hours or less and the water depth increase is typically no more than 3 feet.
- The plants selected should accommodate the hydraulic operation of the wetland. A diversity of native species is best for plant viability. The adaptability of a plant to various water depths and soil and light conditions should also be considered.
- The use of weedy, invasive, or non-native species should be avoided.

Large Storm Conveyance

The wetland should be designed to contain the runoff volume of 90 percent of the annual storm events.

Pretreatment

- Pretreatment of stormwater prior to its introduction into the wetland may be used to prevent sediment and grit loading.

- Pretreatment options include a forebay, filter strips, swales, catch basins, and oil and grit separators.

Operation and Maintenance

The primary maintenance requirement for stormwater wetlands is to inspect the treatment area's components and monitor the accumulation of sediments.

Table 7-7 Stormwater Wetland: Typical Maintenance

Activity	Schedule
• Remove and replace unsuccessful or diseased plants • Remove trash and debris	As needed
• Remove accumulated sediment and debris from the wetland and its control structures	Annually

Example Applications

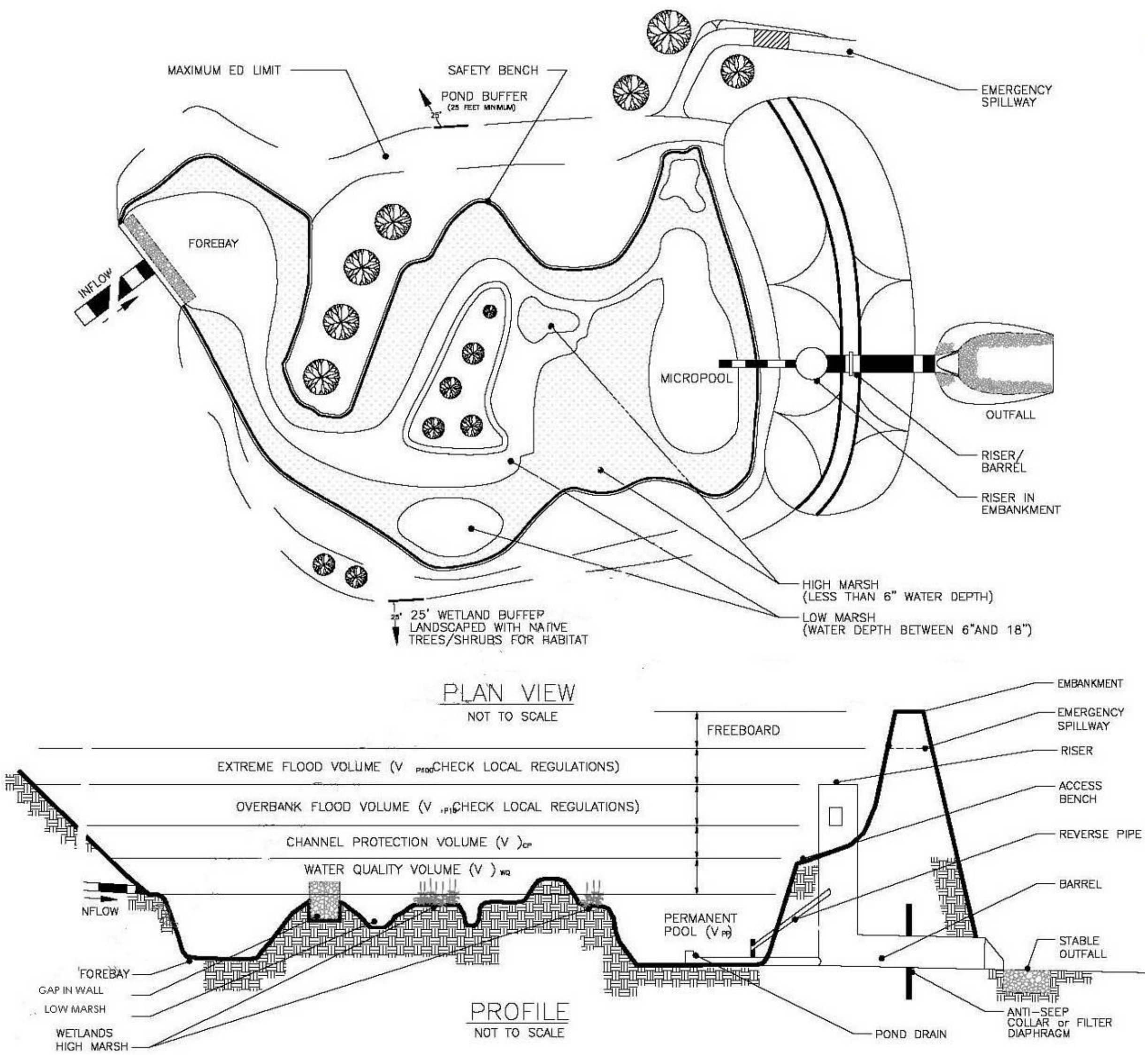
Courtesy of Lake County, Illinois Stormwater Management Commission
Stormwater Wetland in a park

Courtesy of N.C. State University BAE Stormwater Engineering
Stormwater Wetland adjacent to a parking lot/building

Example Design Details

Stormwater Wetland

(Minnesota Stormwater Manual, 2005)



7.8 Dry Wells

Dry well construction

Description

Dry wells are typically gravel or stone filled pits located to catch stormwater from roof downspouts or paved areas.

Benefits and Limitations

- Able to attenuate flow, reduce volume
- Useful for space limited applications
- Promotes infiltration
- Not appropriate for treating runoff from large impervious areas

Suitable Applications

A dry well typically consists of a pit filled with large aggregate such as gravel or stone. Dry wells may also be constructed with a perforated drum placed in a pit and surrounded with stone. These dry well structures are available as commercial products. Dry wells capture and infiltrate water from roof downspouts or paved areas. The surface of the dry well is typically at or just below existing grade and it may be covered by grass or another surface.

Dry wells are suitable for treating small impervious areas and may be useful on steeper slopes where infiltration trenches or other facilities cannot be installed. Dry wells are particularly suited to treat runoff from residential driveways or rooftop downspouts. Installation should be avoided in areas with high sediment loads and in soils with limited permeability. Dry wells are not appropriate for treating runoff from large impervious surfaces such as parking lots.

Required Design Data

- Drainage area
- Native soil infiltration rate

Design Guidelines

Location and Siting

- Dry wells are typically installed on single family residential properties to treat downspout and driveway runoff.
- Useful for reducing erosive runoff from downspouts.
- Dry wells work best in well draining soils.
- Not applicable where groundwater flow will prevent the dry well from draining between storm events.

Physical Specifications

- The minimum separation from the bottom of the dry well to bedrock or to the seasonally high water table is 2 feet.
- Building foundations should be properly sealed to prevent infiltrated water from seeping.
- Non-woven filter fabric can be used to line the well and separate the aggregate from the native soils.

Pretreatment

Pretreatment is typically not provided for dry wells.

Operation and Maintenance

The primary maintenance requirement for dry wells is to inspect them for accumulated debris. Quick inspections of dry wells and gutters should be performed after large storm events.

Table 7-8 Dry Well: Typical Maintenance

Activity	Schedule
• Inspect dry well and gutters for debris accumulation and remove accumulated debris	Semi-annually

Example Applications

Courtesy of Nicholls Landscaping

Residential dry well for roof runoff and sump pump drainage

Example Design Details

Dry Well

(City of Portland, Oregon)

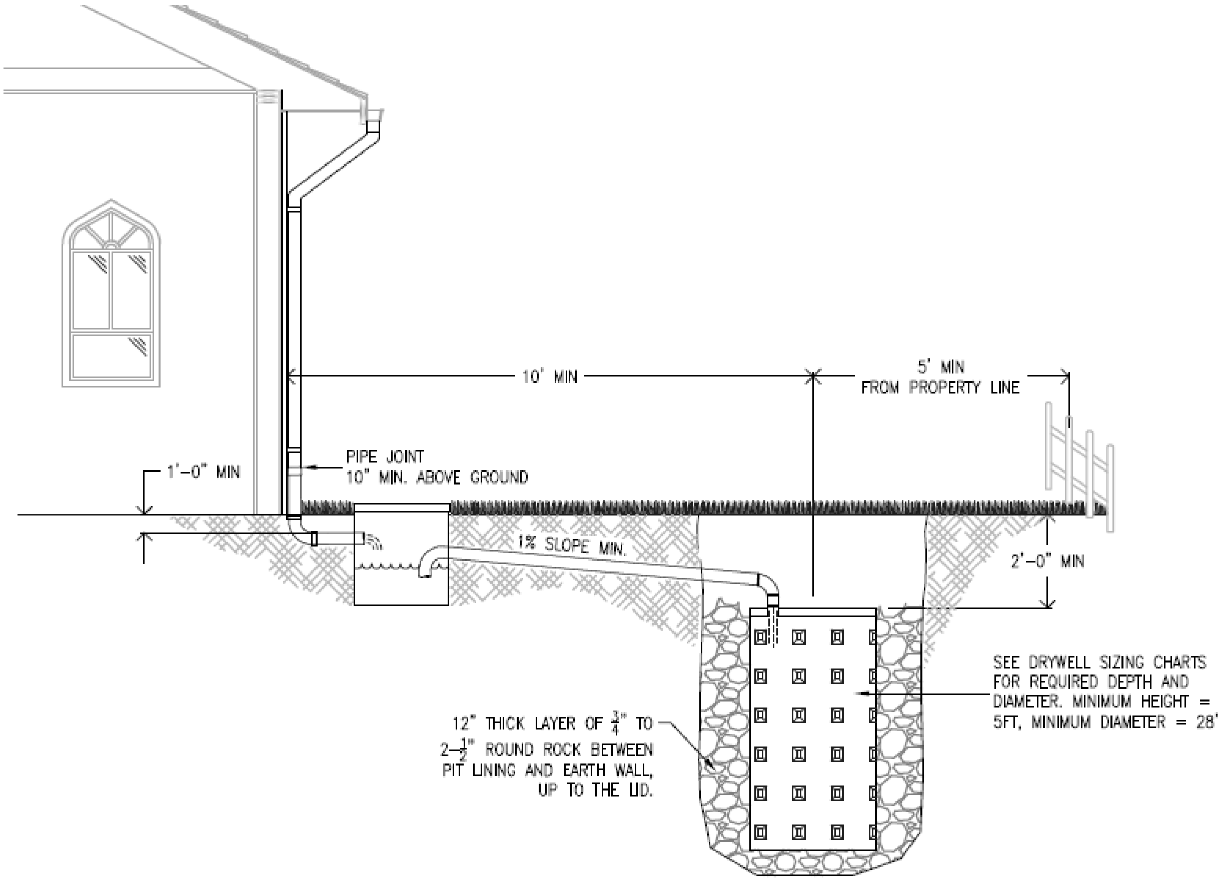


Exhibit 2-36: Drywell Sizing Table

Once approval has been given by BDS for onsite infiltration of stormwater, the following chart shall be used to select the number and size of drywells. Gray boxes are acceptable.

IMPERVIOUS	28" Diameter				48" Diameter			
Area (sq-ft)	Drywell Depth				Drywell Depth			
	5'	10'	15'	20'	5'	10'	15'	20'
1000								
2000								
3000								
4000								
5000								
6000								
7000								
8000								
9000								
10000								

References

Portland, City of, Bureau of Environmental Services. (2008). *Stormwater Management Manual.* Web Site last accessed December 31, 2009. www.portlandonline.com/BES/index.cfm?c=47952

7.9 Pocket Sand Filter

Courtesy of City of Portland, Oregon
Pocket sand filter

Description

A pocket sand filter is a treatment system that is used to remove particulates and solids from stormwater runoff through filtering and physical pollutant removal.

Benefits and Limitations

- Uses physical processes to remove pollutants
- Occupies a small footprint relative to drainage area treated
- Good retrofit capability
- Cannot attenuate volume if stormwater is unable to infiltrate into the native soils

Suitable Applications

A pocket sand filter is designed to improve water quality from impervious drainage areas by filtering runoff through sand. It is primarily used for small sites to treat the water quality volume of runoff. Pollutant removal in pocket sand filters occurs primarily through straining and sedimentation.

Pocket sand filters are designed slightly differently than conventional flow-through systems. Stormwater diverted to the system travels through a flow spreader, across a grass filter strip, and into a plunge pool. From the plunge pool, the stormwater flows into the sand filter, which is covered with a soil layer and grass cover or stone. Often, the water quality volume of runoff is temporarily stored above the filter bed. Once the stormwater flows through the pocket sand filter, it can infiltrate into the native soils or be collected in an underdrain. Pocket sand filters are well suited to treat runoff from small impervious drainage areas.

Required Design Data

- Stormwater quality and quantity design criteria
- Site characteristics
- Drainage area
- Native soil infiltration rate

Design Guidelines

Location and Siting

- Pocket sand filters are designed to treat runoff from small impervious drainage areas and are ideal for sites with limited open space.
- The filter should be sited and the site designed to provide sufficient hydraulic head to allow stormwater to flow through the filter by gravity.
- Perform an analysis of the existing soils at the start of the design phase to determine whether an underdrain is needed.
- Applicable to sites with soils of sufficient hydraulic conductivity or suitable outlet for an underdrain system to allow rapid flow of stormwater through the filter.

Regulatory Criteria

The primary treatment volume is limited to the Water Quality volume (WQv) per Ohio EPA.

Physical Specifications

- A minimum of 2 feet of separation is recommended between the water table and the bottom of the pocket sand filter.
- Pocket sand filters may consist of one or more sedimentation and filtration chambers or areas to treat runoff.
- A shallow excavated basin contains the sand filter layer. The surface of the filter bed may be covered with a soil layer and planted with grass or left as sand or stone.
- A pea gravel well should be installed to direct runoff into the sand in the event of surface clogging.
- In most cases, the filtered runoff is allowed to infiltrate into the underlying soils, although an underdrain and/or adequate subsurface storage may be needed if the soils are not suitably permeable.
- The underdrain collection system, if deemed necessary, is a 6- to 8-inch perforated pipe (typically with a sock) in a gravel layer. The depth of the gravel layer depends on the desired storage capacity but is typically at least 12 inches. If root growth is expected, PVC pipe is recommended so that a rooter can be used to clear the pipe. Five feet or more of underdrain closest to a storm drain tie-in must be non-perforated to prevent exfiltration into the storm drain. The hydraulic capacity of the underdrain should equal or exceed the maximum flow rate through the sand filter.
- Filters deeper than 2 feet and those with underdrains should have one or more observation and cleanout wells, centered in the cell.
- Use locally available sand specification which is generally equivalent to the requirements for fine aggregate contained in ASTM C-33.
- To avoid clogging, do not place any filter fabric horizontally in the sand filter.

Large Storm Conveyance

Bypass flow for extreme events in which the stormwater flow rate to the system exceeds the capacity of the sand filter is diverted by an overflow structure such as a standpipe, riser, or yard inlet. Overflow structures can be designed to safely pass flows from events up to the 100-year storm. Bypass and overflow devices can also be designed as flow splitters, diverting the excess runoff volume away from the filter and into the main conveyance system.

Pretreatment

Pretreatment for pocket sand filters consists of a filter strip and plunge pool or sedimentation basin to remove sediments and particulates prior to the stormwater entering the filter.

Operation and Maintenance

The primary maintenance requirement for pocket sand filters is the removal of trash and accumulated sediment and hydrocarbons. If the filter does not drain within the design drawdown time, the top layer of sand should be replaced. The color of the sand through the cross-section will help to determine the required depth of sand replacement.

Table 7-9 Pocket Sand Filter: Typical Maintenance

Activity	Schedule
• Ensures contributing area, sedimentation basin, inlets, and outlets are clear of debris • Check to ensure the filter surface is not clogging (also after moderate and major storms) • Ensure activities in the drainage area minimize oil/grease and sediment entry to the system • Remove trash and debris	Monthly
• Check to see that the filter bed is clean of sediments, and the sediment chamber is not more than half full of sediment. Remove sediment if necessary • Inspect inlets, outlets, and overflow spillway to ensure good condition, and no evidence of erosion • Repair or replace any damaged structural parts • Ensure that flow is not bypassing the facility	Annually

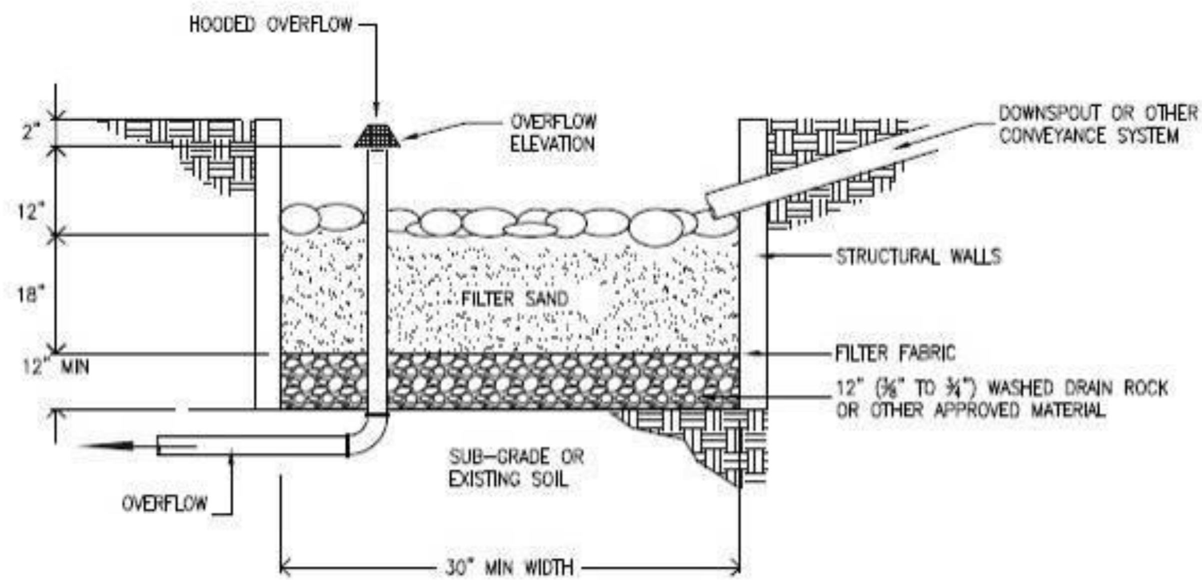
Example Applications

Courtesy of Montgomery County, Maryland
Pocket sand filter in a residential area

Example Design Details

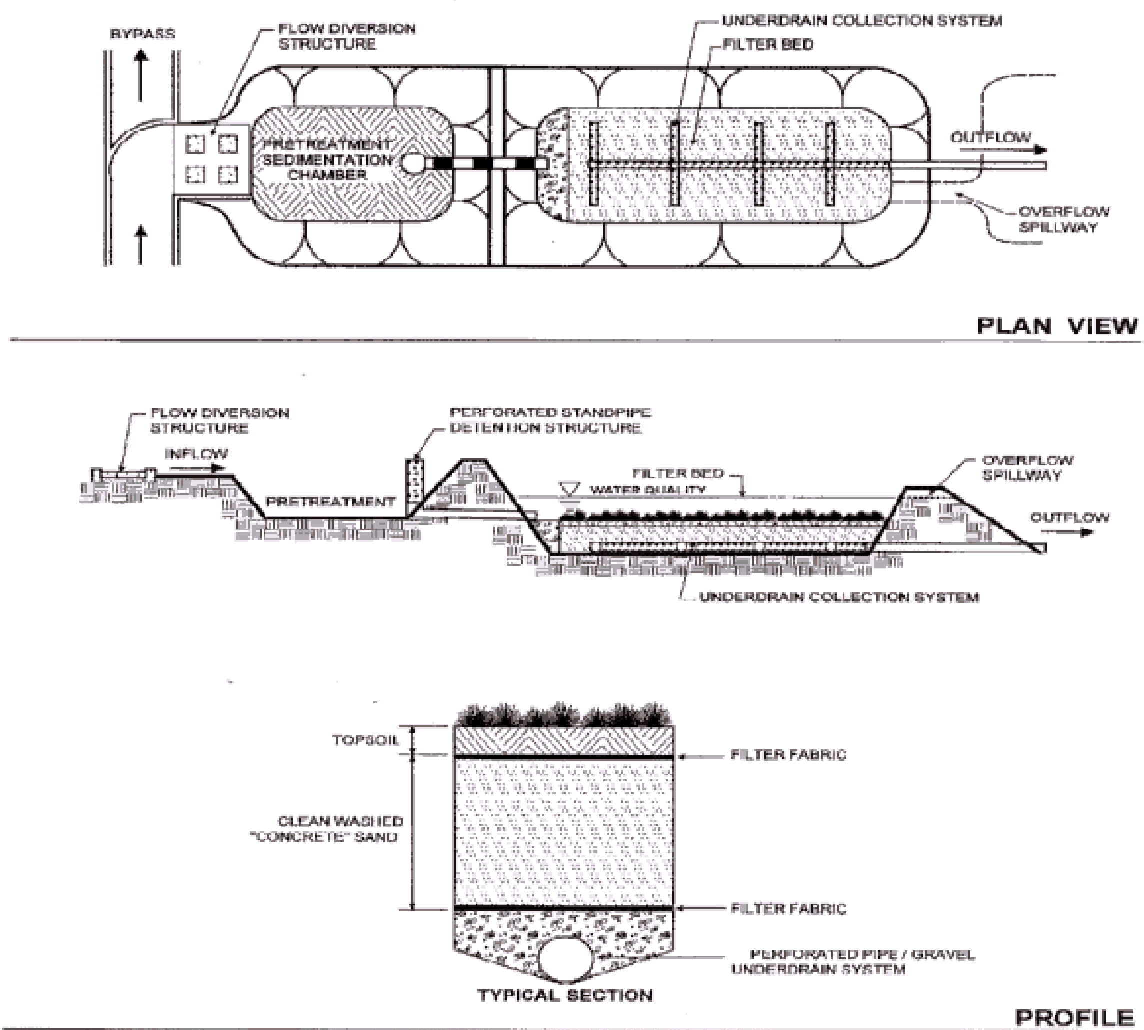
Sand Filter Cross Section

(City of Portland, Oregon)



Sand Filter Cross Section

(Stormwater Center)



7.10 Vegetated Roof

Extensive vegetated roof planted with sedum on a commercial building

Description

Vegetated roofs are used to introduce vegetation onto sections of roof to reduce imperviousness and absorb and filter rainfall. They are typically categorized as either extensive- or intensive-type vegetated roofs. Refer to Sidebar 7-2 for more detail.

Benefits and Limitations

- Uses biological, chemical, and physical processes to remove a variety of pollutants
- Able to attenuate flow, reduce volume
- Good retrofit capability as long as the existing roof is structurally able to support the vegetation and sub-layers
- Reduces impervious area
- Introduces vegetation which improves air quality and lowers urban temperatures
- Wood frame and unreinforced masonry buildings are generally unable to bear the additional load of a vegetated roof
- Design modifications are required to install vegetated roofs on sloped roofs

Suitable Applications

Vegetated roofs consist of a layer of soil media and vegetation that filter, absorb, and retain/ detain the rain that falls upon them. Rainfall that infiltrates into the vegetated roof is lost to evaporation or transpiration by plants, or, once the soil has become saturated, percolates through to the drainage layer and is discharged through the roof downspouts. In unsaturated conditions, vegetated roofs provide high rates of rainfall retention for small storm events. Lower rates of retention are provided for larger storm events but the runoff volume and peak flow rate is reduced because of temporary storage in the soil.

Vegetated roofs may cover large sections of a roof while maintaining access for utilities, maintenance, or recreation. Vegetated roofs are most often applied to buildings with flat roofs, but can be installed on roofs with slopes up to 30 degrees with the use of mesh, stabilization panels, or battens. Slopes greater than 30 degrees require special design considerations.

Required Design Data

- Stormwater quality and quantity design criteria
- Structural characteristics of building

Design Guidelines

Location and Siting

- Vegetated roofs will not cover the entire roof area because of the need to site heating ventilation and air condition systems and to provide roof access for maintenance.
- Vegetated roofs typically cover 50 to 80 percent of the roof area.
- The load of a fully saturated vegetated roof is approximately 6 to 7 pounds per square foot per inch of depth. A 4-inch extensive vegetated roof, for instance, will weigh 24 to 28 pounds per square foot when wet.

Regulatory Criteria

Vegetated roofs can be designed and sized to manage the Water Quality volume (WQv) of runoff as designated per Ohio EPA.

Physical Specifications

- Extensive vegetated roofs, with soil depths of 1 to 6 inches, are most commonly used for stormwater management.
- The soil media for vegetated roofs should be light-weight and largely inorganic.
- Plants selected for vegetated roofs should be hardy, self-sustaining, drought-resistant plants able to withstand daily and seasonal variations in temperature and moisture on rooftops. Typical plants used for extensive roofs are from the genera Sedum and Delosperma.
- A drainage layer installed beneath the vegetated roof routes excess runoff from the roof to the downspouts.
- A root barrier installed below the drainage layer prevents plant roots from damaging structural roof membranes.
- A waterproof membrane is used to prevent transmission of moisture from the vegetated roof to the structural roof.
- An insulation layer between the vegetated roof and structural roof can improve the thermal qualities of the system.
- An optional leak detection membrane can be used to assess the integrity of the waterproof membrane.

Sidebar 7-2
Intensive versus Extensive Vegetated Roofs

Extensive vegetated roofs feature a layer of growing medium that is 6 inches deep or less and are generally planted with sedums or native plant species. Extensive vegetated roofs are generally not accessible to the public.

Intensive vegetated roofs are generally designed as amenity space that can be used by building tenants or by the general public. Intensive vegetated roofs are generally heavier and need substantial structural support. They include a deeper layer of growing medium, support a wider variety of plants, and have greater need for irrigation and maintenance.

Semi-intensive vegetated roofs include features of both intensive and extensive green roofs. These are referred to as semi-intensive green roofs.

Source: Minnesota Green Roofs Council
www.mngreenroofs.org/types

Emergency Spillway

When fully saturated, vegetated roofs will infiltrate rainwater and channel it to the roof downspouts for discharge.

Pretreatment

Pretreatment is not used prior to vegetated roofs.

Operation and Maintenance

The maintenance for an established vegetated roof is minimal and generally consists of inspecting and caring for the vegetation.

Table 7-10 Vegetated Roof: Typical Maintenance

Activity	Schedule
• Water vegetation as necessary during establishment	As needed
• Inspect for and repair leaks • Weed vegetated roof and remove and replace unsuccessful or diseased plants • Replant bare spots in soil	Annually

Example Applications

Vegetated roof on a municipal building

Vegetated roof on a home

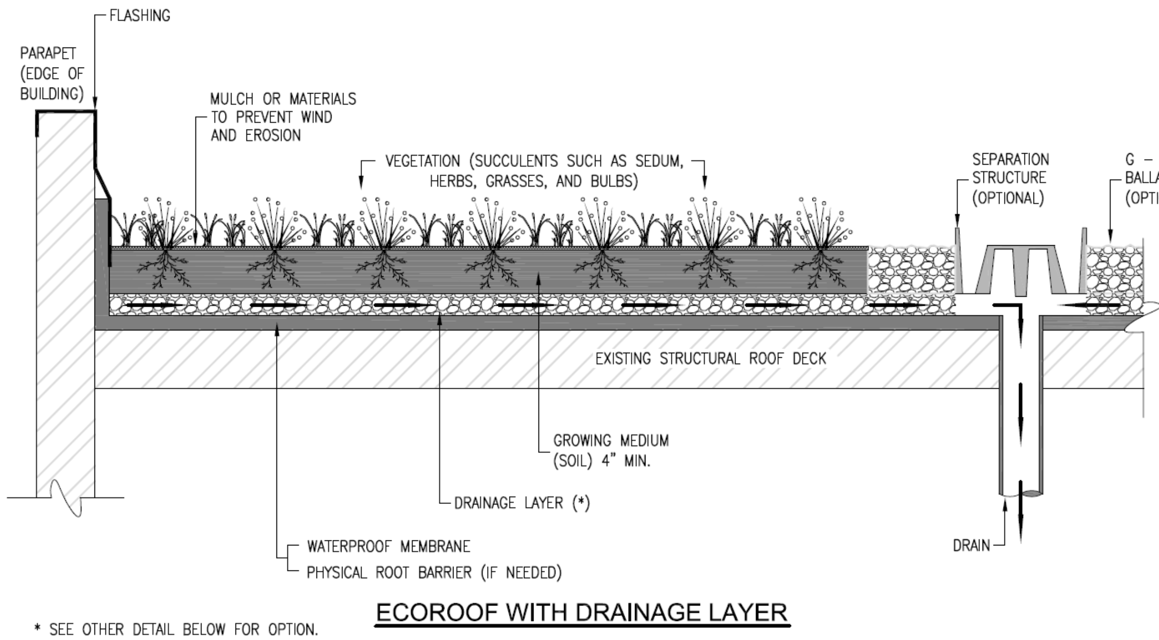
Courtesy of Haworth Corporation
Grand Rapids, Michigan

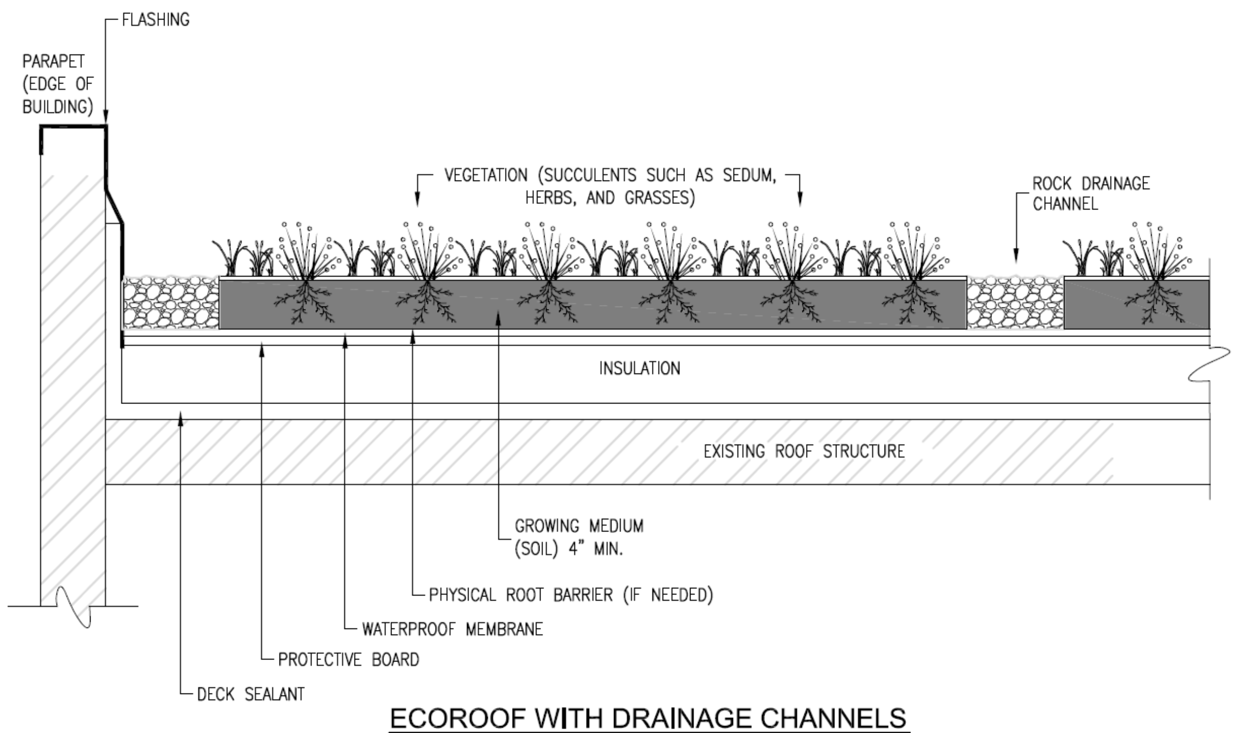
Vegetated roof on a commercial building

Example Design Details

Vegetated Roof

(City of Portland, Oregon)





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7.11 Proprietary Devices

Stormwater vault

Description

Proprietary devices typically consist of catch basin controls or stand-alone vaults that prevent sediment, oils, floatable trash, and debris from being transmitted through the collection system.

Benefits and Limitations

- Prevents trash and debris from entering the stormwater collection system
- Good retrofit capability
- Provide limited water quality treatment
- Do not attenuate peak flows or volume
- Provide lesser treatment than other BMPs

Suitable Applications

Proprietary devices are typically installed underground in stormwater catch basins or as stand-alone vaults. For instance, several catch basin insert devices are available that use screens, baffles, filter fabrics, and absorbents to capture and retain pollutants within the catch basin. Oil-water separators, sedimentation tanks, and hydrodynamic separators (flow-through devices with a settling or separation unit) are examples of proprietary devices that can be used to remove sediments and other stormwater pollutants. A variety of devices and manufacturers exist, and new products are continuously emerging.

For more information on proprietary devices on the market, refer to *Stormwater BMPs: Selection, Maintenance, and Monitoring* by G. England and S. Stein (England and Stein, 2007).

Proprietary devices may be used by themselves or with other BMPs as part of a stormwater treatment train. However, these controls are generally considered pretreatment devices, as they typically provide limited treatment when compared to other BMPs.

Required Design Data

- Stormwater quality and quantity design criteria
- Site characteristics
- Drainage area
- Collection system criteria

Design Guidelines

Location and Siting

- Proprietary devices are often installed in closed section roadways to allow curbs and inlets to channel runoff to the catch basins or device locations.
- When used in catch basins, it is preferred to install proprietary devices in the basins with the largest volumes to increase treatment effectiveness and reduce maintenance frequency.
- Proprietary devices must be installed to provide easy access for regular maintenance.
- Facility elevations (inlet, outlet) must be carefully assessed to provide pollutant removal and proper conveyance to the collection system.

Regulatory Criteria

Proprietary devices are often sized and situated to provide treatment of the Water Quality volume (WQv) of runoff per Ohio EPA.

Physical Specifications

- Proprietary devices can be installed upstream or downstream of the collection system depending on the device.
- Required vaults can be pre-cast, cast-in-place concrete, or plastic.
- Specifications for proprietary devices are based upon manufacturer recommendations.

Emergency Spillway

Proprietary devices most often act as pre-filtration or separation units that do not impede the flow of stormwater to the collection system. For units in stand-alone vaults, emergency bypasses are used to convey excess flows around the treatment unit to the collection system.

Pretreatment

Pretreatment is generally not provided for proprietary devices.

Operation and Maintenance

The primary maintenance requirement for proprietary devices is to remove accumulated pollutants, sediments, and trash and inspect the device for deterioration and operation.

Table 7-11 Proprietary Devices: Typical Maintenance

Activity	Schedule
• Inspect device and remove accumulated pollutants and debris • Check sediment depth and surface pollutants to plan additional maintenance	Quarterly

Devices should be cleaned if a spill or other incident causes a larger than normal accumulation of pollutants in a structure. If oil absorbent hydrophobic booms are being used in the structure to enhance hydrocarbon capture and removals, they should be checked monthly. All collected wastes must be handled and disposed of according to local environmental requirements.

7.12 Cisterns and Rain Barrels

Description

Cisterns and rain barrels capture and store rainwater as a means of reducing stormwater runoff and providing a non-potable water source for irrigation and grey water uses.

Courtesy of Kresge Foundation Headquarters, Troy, Michigan

Above ground cistern

Benefits and Limitations

- Able to attenuate flow, reduce volume
- Reduces water demand by providing an alternative source of non-potable water
- Provides an inexpensive source of water
- Requires a dedicated piping system when used for indoor uses

Suitable Applications

Cisterns typically hold several hundred to several thousand gallons of rainwater. They can be used in a variety of settings (single- and multi-family residential, commercial, government, industrial) to provide non-potable water. Harvested rainwater is ideal for outdoor irrigation, toilet and urinal flushing, cooling system make-up, and equipment and vehicle washing. There are numerous rainwater harvesting products on the market to assist with storing and distributing rainwater for non-potable water uses.

Rain barrels function similarly to cisterns but they tend to be smaller (less than 100 gallons), very simple, and are primarily used on single-family homes. Rain barrels are usually situated at the discharge point of roof downspouts and are a convenient source of water for gardening. Rain barrels are sold commercially and are sometimes available through the local municipality.

The rainwater collection area for cisterns and rain barrels is usually limited to rooftops because they contain lesser concentrations of pollutants than runoff from other surface areas. While cisterns can be used in any setting, they are particularly useful as a method of reducing stormwater runoff volumes in urban areas where site constraints limit the use of other BMPs. Due to their small size, rain barrels usually do not have a measurable impact on reducing runoff volumes.

Required Design Data

- Rainfall data
- Area of roof used for rainwater harvesting
- Water demand of identified end uses

Design Guidelines

Location and Siting

- Cisterns can be installed above or below grade, indoors or out.
- Positive outlet for overflow should be provided a few inches from the top of the cistern and should be sized to safely discharge excess volume when the tank is full.
- When cisterns are installed below grade, observation risers should rise at least 8 inches above grade.
- Outdoor cisterns should be constructed of dark materials or otherwise shaded or buried to protect the harvested rainwater from direct sunlight which can cause algal growth.
- Cistern overflows should be directed away from structures and to pervious areas to allow for infiltration, whenever possible.
- Outdoor cisterns should contain adequate screening at each opening to prevent insects from entering.

Regulatory Criteria

The use of cisterns for non-potable water supply will be governed by local plumbing and health regulations.

Physical Specifications

- Cisterns are typically prefabricated, made of plastic, metal, or concrete. They can also be cast in place.
- Materials used for cisterns should be rated for potable water use or lined with a material rated for potable use.
- A make-up water supply of municipal water should be provided to the cistern to augment rainwater in times of limited rainfall and when rainwater supply is insufficient to meet demand.
- A backflow prevention assembly on the potable water supply line, an air gap, or both should be used to prevent cross-contamination.
- The use of a designated, dual piping system is necessary to deliver harvested rainwater to end uses.
- A specified colored pipe indicating rainwater should be accompanied by pipe stenciling and point-of-contact signage that indicates the water is non-potable and not for consumption.
- A pump is often required to deliver the rainwater from the cistern. The pump should be capable of delivering the needed capacity at necessary pressure.
- All components of the distribution system should be constructed of materials rated for potable water use.

Emergency Overflow

First flush diverters and roof washers are designed to bypass cisterns and allow rainwater to discharge through the downspouts once cisterns are full. In addition, a tank overflow is provided on the cistern to discharge excess volume.

Pretreatment

- Treatment of harvested rainwater is intended to prevent fouling of the cistern and collection system and condition the water as needed for the end use.
- Roof gutters supplying the cistern should be equipped with leaf screens with openings no larger than ½-inch across their entire length including the downspout opening. The screens prevent debris from clogging the collection system and/or fouling the harvested water. For internal downspouts, the downspout opening should be screened.
- A first flush diverter may be used to allow the initial portion of runoff (e.g., 10 gallons per 1,000 square feet of collection area) to bypass the cistern.
- Roof washers may be used for additional treatment. They can act as first flush diverters and also contain filter media (e.g., sand, gravel, filter fabric) to provide removal of particulates that have passed through the leaf screens.
- Additional filtration and disinfection may be provided following the cistern and prior to water use.

Operation and Maintenance

The primary maintenance requirement for cisterns is to inspect the tank and distribution system and test any backflow prevention devices. Generally, maintenance is the same as the routine periodic maintenance for on-site drinking water wells.

Table 7-12 Cisterns: Typical Maintenance

Activity	Schedule
• Remove tree branches and vegetation overhanging roof	As needed
• Inspect and clean filters and screens	Quarterly
• Inspect and clear debris from roof, gutters, downspouts, and roof washers	Semi-annually
• Inspect pumps, valves, and pressure tanks and verify operation • Inspect cistern and system labeling • Inspect backflow prevention system	Annually

Example Applications

Rain barrel collecting roof runoff at a municipal building

Courtesy of The Texas Water Development Board

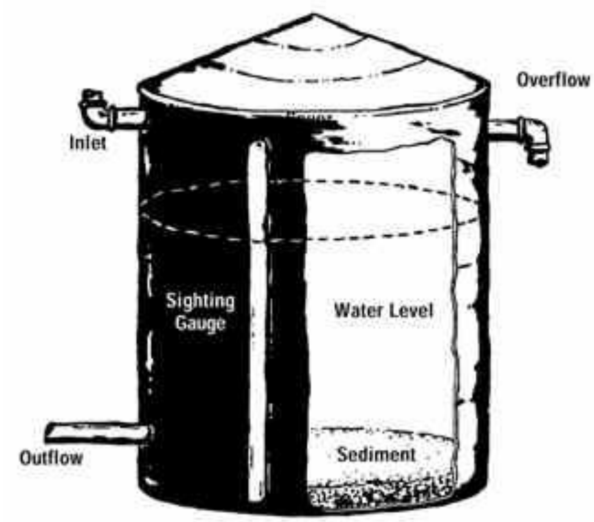
Cistern collecting roof runoff at a commercial building

Backyard rain barrel

Example Design Details

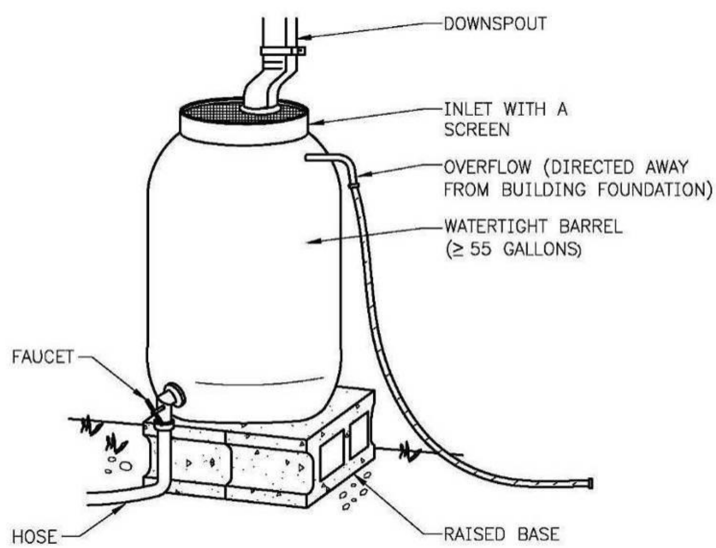
Cistern

(Low Impact Development Center)



Rain Barrel

(City of Dayton, Ohio)



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8.0 PLANTS FOR STORMWATER DESIGN

This chapter provides guidelines for planting and maintaining native plant species in the stormwater BMP structures detailed in this manual. Due to their adaptation to local conditions such as growing season, average temperature, moisture availability, and soil type, native plants are the best choice for populating stormwater BMP structures. A detailed table is provided below listing native plant requirements for sunlight, soil moisture, and salt tolerance as well as the color, average mature height and bloom time.


Courtesy of Jan Hunter, Naturally Native Nursery
Swamp Milkweed

8.1 Planting Guidelines

Each native plant has preferred sunlight and soil moisture requirements for optimal growth. Sunlight requirements include full sun, partial sun tolerant, and shade tolerant. Plants also have optimal soil moisture requirements ranging from wet (water saturated most of the time), to mesic (average garden soil), to dry (well-drained). Many plants have a wide range of tolerance for sunlight and moisture while others have very specific preferences.

Seeding

Seeding is generally recommended for larger areas and locations that do not contain standing water. On graded or bare soil areas, broadcast seeding using a combination seeder/cultipacker unit such as a Brillion or Truax Trillion seeder (the Trillion seeder is specifically designed to handle native seeds) is the preferred method. A cone seeder may be used if the seed mix does not contain fluffy seeds in amounts that would clog the device. Seeds should be pressed into the soil after broadcasting using a cultipacker or roller. A rangeland-type, no-till drill may also be used to plant native seeds on bare soil although cultipacking or rolling may be required prior to planting to prevent seeds from being planted too deep. Refer to Sidebar 8-1 for recommended seeding rates.

Sidebar 8-1 Seeding Rates and Plug Planting Densities

Seeding Rates

Grasses: 7 to 10 lbs per acre

Perennial Flowers:
2 to 5 lbs per acre

Source:
www.fhwa.dot.gov/environment/rdsduse/rd_use11.htm

Plug Planting Densities

Seeded Areas:
3- to 5-foot spacing

High Visibility Landscaping:
6- to 24-inch spacing

Seeding equipment should be calibrated prior to use to ensure seed delivery at the rates and proportions specified in the site plans. Care should be taken that the entire planting area is uniformly covered and that the seed is planted no deeper than 0.25 inches in the soil. Fertilization and soil conditioning are not typically required.

Planting

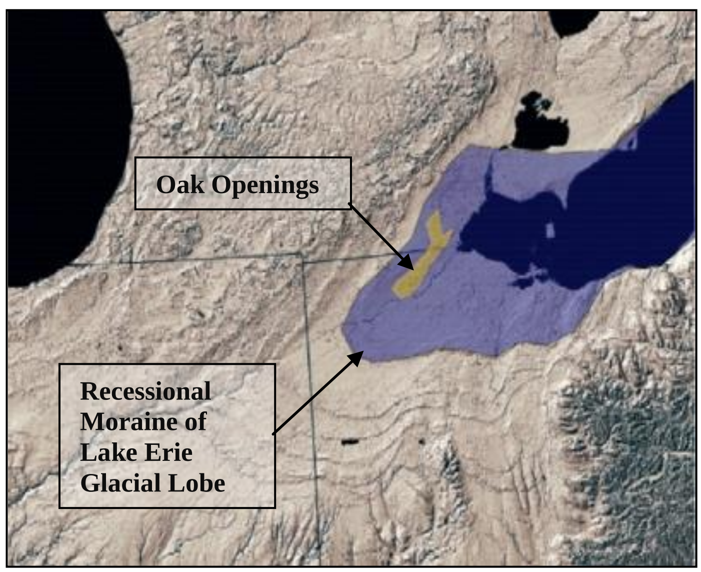
In smaller areas or in wetlands, plant plugs are the preferred method of establishing a native planting. Plugs should be installed in holes drilled with an auger that is the same diameter or slightly larger than the plug. In wetlands where soil is soft and moist, a dribble bar or trowel may be used. Planting densities vary according to project size and budget. See Sidebar 8-1 for suggested planting densities. The site planting layout should reflect the requirements for soil type, moisture, and shading for each individual plant species. Plugs installed in areas with high potential for erosion should be secured with wire erosion control blanket staples, and wildlife barriers should be installed where the potential for predation or wildlife damage exists.

Maintenance

Maintenance of a native planting is most critical for the first few years, or until the native vegetation becomes established. During the establishment period, irrigation may become necessary during prolonged periods of drought. Controlling weeds and invasive plants by hand weeding, mowing, or selective herbicide application may also be necessary. Some plants may need replacement due to unforeseen circumstances.

Long-term maintenance of a native planting is usually much less intensive due to the vigorous nature of native plants and their ability to outperform invasive weeds. In upland areas, periodic burning or cutting of the planted area may be required to control invasive woody plants. For more information on prescribed burnings, visit the Ohio Department of Natural Resources website at **http://ohiodnr.gov/forestry/fire/prescribedfire2/tabid/5141/Default.aspx**.

Figure 8-1 Oak Openings Ecoregion



Courtesy of Paul Morin, National Center for Earth-surface Dynamics, and NSF Science and Technology Center, and the University of Minnesota

8.2 Oak Openings Ecoregion

The Oak Openings area of northwest Ohio and southeast Michigan is a unique and internationally recognized ecoregion that deserves special consideration when making native plant choices. This area of wet meadows interspersed among oak savannah has historically supported a distinctive plant community that is currently threatened by development. Refer to Figure 8-1 showing the location of the Oak Openings area (in yellow). By using plants in stormwater BMP structures that are endemic to the Oak Openings ecoregion, a project can help support the area's unique biodiversity. Plants that are native to the Oak Openings community are noted in Table 8-1.

Courtesy of Robert Domm
Royal Catchfly

8.3 Northwest Ohio Native Plant Characteristics

The following plant characteristics table (Table 8-1) was compiled from the Northwest Ohio Native Plant Working Group list. The list includes trees, shrubs and vines, perennial forbes, grasses, and ferns that are suitable for native plantings in northwest Ohio. The table gives guidelines for soil moisture [wet (W), mesic (M), dry (D)], sunlight requirements [full sun (FS), partial sun (PT), shade (SH)], and tolerance for salt. For landscape design, the table also gives the average height of the mature plant, the bloom color, and the normal bloom time.

Courtesy of Jan Hunter
Naturally Native Nursery
New England Aster

Courtesy of Robert Domm
Columbine

Courtesy of Robert Domm
Purple Coneflower

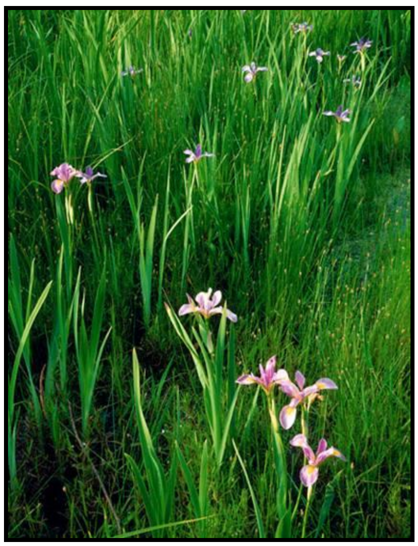
Courtesy of Robert Domm
Rattlesnake Master


Courtesy of Robert Domm
Blazing Star


Courtesy of Jan Hunter
Naturally Native Nursery
Purple Joe-Pye Weed


Courtesy of Robert Domm
Yellow Coneflower


Courtesy of Robert Domm
Wild Bergamot


Courtesy of Robert Domm
Blue Flag Iris


Courtesy of Robert Domm
Ironweed


Courtesy of Robert Domm
Black-Eyed Susan

Table 8-1 Northwest Ohio Native Plants

Common Name	Type	Scientific Name	Soil Moisture	Sun	Salt Tolerance**	Height	Blossom Color	Bloom Time
Beardtongue/Smooth Penstemon*	perennial forb	Penstemon digitalis	M/D	FS/PT/SH	no	4'	white	Jun-Jul
Big Bluestem*	Grass	Andropogon gerardii	M/D	FS/PT	no	7'	--	--
Black Haw	tree, shrub, vine	Viburnum prunifolium	M	FS/PT	no	to 16'	cream	May-Jun
Black-Eyed Susan*	perennial forb	Rudbeckia hirta	M	FS/PT	yes	2'	yellow	Jun-Oct
Blue Flag Iris*	perennial forb	Iris virginica shrevei	W/M	FS/PT	no	3'	blue	May-Jul
Blue Joint Grass*	Grass	Calamagrostis canadensis	W/M	FS/PT	no	4'	--	--
Blue Vervain*	perennial forb	Verbena hastata	W/M	FS/PT	no	5'	blue	Jul-Sept
Bottlebrush Grass	Grass	Hystrix patula	M/D	PT/SH	unknown	3'	--	--
Brown-Eyed Susan	perennial forb	Rudbeckia triloba	M	FS/PT	no	5'	yellow	Aug-Oct
Bur Oak	tree, shrub, vine	Quercus macrocarpa	M	FS/PT/SH	no	80'	green	--
Butterflyweed*	perennial forb	Asclepias tuberosa	M/D	FS/PT	yes	2'	orange	Jun-Aug
Buttonbush*	tree, shrub, vine	Cephalanthus occidentalis	W	FS/PT	no	to 15'	white	Jun-Aug
Canada Wild Rye	Grass	Elymus canadensis	M/D	FS/PT	no	5'	--	--
Cardinal Flower*	perennial forb	Lobelia cardinalis	W	FS/PT	no	4'	red	Jul-Sept
Cinnamon Fern*	Ferns	Osmunda cinnamomea	W/M	PT	unknown	3'	brown	Mar-May

Common Name	Type	Scientific Name	Soil Moisture	Sun	Salt Tolerance**	Height	Blossom Color	Bloom Time
Common Blue-eyed Grass	perennial forb	Sisyrinchium albidum	D	FS/PT	unknown	6"	blue	May-Jun
Common Boneset*	perennial forb	Eupatorium perfoliatum	W	FS/PT	yes	4'	white	Jul-Sept
Common Fox Sedge*	Grass	Carex stipata	W/M	FS/PT/SH	no	3'	--	--
Common Milkweed*	perennial forb	Asclepias syriaca	M/D	FS/PT	no	3'	purple	Jun-Aug
Common Witch Hazel*	tree, shrub, vine	Hamamelis virginiana	M	PT/SH	no	to 20'	yellow	Sept-Oct
Compass Plant	perennial forb	Silphium laciniatum	M/D	FS/PT	no	8'	yellow	Jun-Sept
Cord Grass	Grass	Spartina pectinata	W/M	FS/PT	yes	8'	--	--
Culver's Root*	perennial forb	Veronicastrum virginianum	M	FS/PT	no	5'	white	Jun-Aug
Cup Plant	perennial forb	Silphium perfoliatum	M	FS/PT	no	8'	yellow	Jul-Sept
Dense (Marsh) Blazing Star*	perennial forb	Liatris spicata	W/M	FS/PT	no	5'	purple	Jul-Sept
Dotted Horsemint*	perennial forb	Monarda punctata	D	FS/PT	unknown	2'	purple	Jul-Sept
Downy Sunflower	perennial forb	Helianthus mollis	--	--	no	--	--	--
Elderberry*	tree, shrub, vine	Sambucus canadensis	M	FS/PT	unknown	to 10'	white	Jun-Aug
Elm-leaved Goldenrod	perennial forb	Solidago ulmifolia	M	PT/SH	unknown	3'	yellow	Jul-Oct
Flat-topped Aster*	perennial forb	Aster umbellatus	M	PT	no	4'	white	Jul-Sept
Flowering Spurge*	perennial forb	Euphorbia corollata	M/D	FS/PT	no	3'	white	Jun-Aug

Common Name	Type	Scientific Name	Soil Moisture	Sun	Salt Tolerance**	Height	Blossom Color	Bloom Time
Giant Sunflower*	perennial forb	Helianthus giganteus	W/M	FS/PT	no	8'	yellow	Jul-Sept
Grayheaded (Yellow) Coneflower*	perennial forb	Ratibida pinnata	M	FS/PT	no	5'	yellow	Jul-Sept
Great Blue Lobelia*	perennial forb	Lobelia siphilitica	W/M	FS/PT	no	3'	blue	Jul-Oct
Green-headed Coneflower*	perennial forb	Rudbeckia laciniata	M/D	FS/PT/SH	no	7'	yellow	Jul-Oct
Hairy Mountain Mint	perennial forb	Pycnanthemum pilosum	M	FS/PT	no	3'	white	Jul-Aug
Heath Aster*	perennial forb	Aster ericoides	M	FS/PT	unknown	3'	white	Sept-Oct
Hoary Vervain*	perennial forb	Verbena stricta	D	FS	no	3'	purple	Jun-Aug
Hollow Joe-Pye Weed*	perennial forb	Eupatorium fistulosum	W/M	FS/PT	no	7'	mauve	Jun-Aug
Indian Grass*	Grass	Sorghastrum nutans	M/D	FS/PT	no	6'	--	--
Ironweed*	perennial forb	Vernonia altissima	M	FS/PT	no	6'	purple	Jul-Sept
Jack-in-the-Pulpit*	perennial forb	Arisaema triphyllum	M	PT/SH	unknown	2'	green	Apr-Jul
Jacob's Ladder	perennial forb	Polemonium reptans	M	FS/PT/SH	unknown	1'	blue	Apr-Jun
Jewelweed (Touch me not)*	perennial forb	Impatiens capensis	W/M	FS/PT/SH	unknown	4'	orange	Jun-Sept
June Grass*	Grass	Koeleria cristata	D	FS	no	2'	--	--
Lady Fern*	Ferns	Athyrium filix-femina	W/M	FS/PT/SH	unknown	1'	green	--
Lead Plant	tree, shrub, vine	Amorpha canescens	M/D	FS/PT	unknown	3'	purple	Jun-Aug

Common Name	Type	Scientific Name	Soil Moisture	Sun	Salt Tolerance**	Height	Blossom Color	Bloom Time
Little Bluestem	grass	Andropogon scoparius	M/D	FS/PT	unknown	3'	--	--
Mayapple*	perennial forb	Podophyllum peltatum	M	FS/PT	unknown	1'	white	May-Jun
Meadow/ Canada Anemone	perennial forb	Anemone canadensis	W/M	FS/PS	no	1'	white	May-Jun
Meadowsweet*	tree, shrub, vine	Spiraea alba	W	FS/PT	yes	4'	white	Jun-Sept
Monkeyflower*	perennial forb	Mimulus ringens	W	FS/PT	no	2'	purple	Jul-Sept
New England Aster*	perennial forb	Aster novae-angliae	W/M	FS/PT	no	4'	purple	Aug-Oct
New Jersey Tea*	tree, shrub, vine	Ceanothus americanus	M/D	FS/PT	no	3'	white	Jun-Aug
Nodding Wild Onion*	perennial forb	Allium cernuum	M	FS/PS	no	18"	lavender	Jul-Aug
Obedient Plant	perennial forb	Physostegia virginiana	W/M	FS/PT	yes	4'	pink	Aug-Sept
Pale Purple Coneflower	perennial forb	Echinacea pallida	M/D	FS/PT	no	3'	purple	Jun-Jul
Partridge Pea	perennial forb	Cassia fasciculata	M/D	FS/PT	unknown	2'	yellow	Jul-Sept
Pasture Rose*	tree, shrub, vine	Rosa carolina	M/D	FS/PT	no	2'	pink	Jun-Aug
Pin Oak*	tree, shrub, vine	Quercus palustrus	M	FS/PT/SH	yes	80'	green	--
Plains Oval Sedge*	grass	Carex brevior	M/D	FS/PT/SH	no	1'	--	--
Porcupine Sedge	grass	Carex hystericina	W	FS	no	3'	--	--
Prairie Blazing Star	perennial forb	Liatris pycnostachya	W/M	FS/PT	no	4'	purple	Jul-Sept

Common Name	Type	Scientific Name	Soil Moisture	Sun	Salt Tolerance**	Height	Blossom Color	Bloom Time
Prairie Dock	perennial forb	Silphium terebinthinaceum	M	FS/PT	no	9'	yellow	Jul-Sept
Prairie Ninebark*	tree, shrub, vine	Physocarpus opulifolius	M	FS/PT	no	8'	white	July
Prairie Phlox	perennial forb	Phlox pilosa	M/D	FS/PT	no	2'	pink	May-Jul
Prickly Pear Cactus*	perennial forb	Opuntia humifusa	D	FS/PT	unknown	6"	yellow	Jun-Jul
Purple Coneflower	perennial forb	Echinacea purpurea	M	FS/PT	no	4'	purple	Jul-Sept
Purple Joe-Pye weed	perennial forb	Eupatorium purpureum	M	FS/PT	no	4'	mauve	Jun-Aug
Purple Love Grass*	grass	Eragrosis spectabillis	D	FS/PT	no	2'	--	--
Purple Prairie Clover	perennial forb	Petalostemum purpurea	M/D	FS/PT	unknown	2'	purple	Jul-Sept
Rattlesnake Master	perennial forb	Eryngium yuccifolium	M	FS	no	4'	white	Jul-Sept
Red Oak*	tree, shrub, vine	Quercus rubra	M	FS/PT/SH	no	90'	green	--
Red Osier Dogwood*	tree, shrub, vine	Cornus stolonifera	W/M	FS/PT	no	to 10'	white	Jun-Sept
Riddells Goldenrod*	perennial forb	Solidago riddellii	W/M	FS	no	3'	yellow	Aug-Oct
Rough Blazing Star*	perennial forb	Liatris aspera	M/D	FS/PT	yes	3'	purple	Jul-Oct
Round-headed Bush Clover*	perennial forb	Lespedeza capitata	M/D	FS/PT	no	4'	green	Aug-Sept
Royal Catchfly	perennial forb	Silene regia	M/D	FS/PT	unknown	4'	red	July-Aug
Sand Cherry*	tree, shrub,	Prunus pumila	W/M/D	FS/PT	unknown	5'	white	May-Jun

Common Name	Type	Scientific Name	Soil Moisture	Sun	Salt Tolerance**	Height	Blossom Color	Bloom Time
	vine							
Sand Coreopsis*	perennial forb	Coreopsis lanceolata	D	FS/PT	no	2'	yellow	May-Jul
Sand Dropseed*	grass	Sporobolus cryptandrus	D	FS	unknown	3'	--	--
Sawtooth Sunflower*	perennial forb	Helianthus grosseserratus	M	FS/PT	unknown	8'	yellow	Aug-Oct
Scaly Blazing-star	perennial forb	Liatris squarrosa	D	FS/PT	unknown	2'	purple	Jul-Sept
Sensitive Fern*	ferns	Onoclea sensibilis	W/M	FS/PT/SH	unknown	1'	green	--
Showy Goldenrod*	perennial forb	Solidago speciosa	M/D	FS/PT	yes	5'	yellow	Aug-Oct
Showy Tick Trefoil*	perennial forb	Desmodium canadense	M	FS/PT	no	5'	purple	Jul-Aug
Side Oats Grama	grass	Bouteloua curtipendula	M/D	FS	unknown	2'	--	--
Silky Dogwood*	tree, shrub, vine	Cornus amomum obliqua	W/M	FS/PT	no	to 10'	white	May-Jul
Sky Blue Aster*	perennial forb	Aster azureus	M/D	FS/PT	yes	3'	blue	Aug-Oct
Smooth Aster*	perennial forb	Aster laevis	M	FS/PT	yes	4'	blue	Aug-Oct
Sneezeweed	perennial forb	Helenium autumnale	W	FS	yes	3'	yellow	Aug-Oct
Spicebush*	tsv	Lindera benzoin	W/M	FS/PT	no	to 12'	yellow	May-Jun
Spiderwort*	perennial forb	Tradescantia ohiensis	W/M/D	FS/PT	no	3'	purple	May-Jul
Spotted Joe-Pye Weed*	perennial forb	Eupatorium maculatum	W	FS/PT	no	5'	pink	Jun-Aug

Common Name	Type	Scientific Name	Soil Moisture	Sun	Salt Tolerance**	Height	Blossom Color	Bloom Time
Spreading Oval Sedge	grass	Carex normalis	M	FS/PT/SH	unknown	3'	--	--
Spring Beauty	perennial forb	Claytonia virginiana	W/M	PT/SH	unknown	6"	white	Apr-May
Stiff Goldenrod*	perennial forb	Solidago rigida	M/D	FS/PT	unknown	4'	yellow	Aug-Oct
Swamp Milkweed*	perennial forb	Asclepias incarnata	W/M	FS	no	4'	red/pink	Jun-Aug
Swamp Rose*	tree, shrub, vine	Rosa palustris	M	FS/PT	no	5'	pink	Jun-Aug
Swamp White Oak*	tree, shrub, vine	Quercus bicolor	W/M	FS/PT/SH	no	70'	green	--
Sweet Joe-Pye Weed	perennial forb	Eupatorium purpureum	M	PT/SH	unknown	7'	pink	Jul-Sept
Switch Grass*	grass	Panicum virgatum	M/D	FS/PT	yes	4'	--	--
Tall Coreopsis*	perennial forb	Coreopsis tripteris	M	FS/PT	no	7'	yellow	Jul-Oct
Tall Meadowrue*	perennial forb	Thalictrum polygamum	M	PT/SH	no	2'	green	Apr-May
Tall Thimbleweed*	perennial forb	Anemone virginiana	M/D	FS/PT/SH	unknown	3'	white	Jun-Aug
Turtlehead*	perennial forb	Chelone glabra	W	FS	no	5'	cream	Jul-Sept
Virginia Mountain Mint*	perennial forb	Pycnanthemum virginianum	W/M	FS/PT	no	3'	white	Jun-Sept
Virginia Waterleaf	perennial forb	Hydrophyllum virginianum	W/M	SH	unknown	1'	white	Apr-May
Virginia Wild Rye*	grass	Elymus virginicus	W/M	FS/PT/SH	no	4'	--	--
Western Sunflower*	perennial forb	Helianthus occidentalis	M/D	FS/PT	no	3'	yellow	Jul-Sept

Common Name	Type	Scientific Name	Soil Moisture	Sun	Salt Tolerance**	Height	Blossom Color	Bloom Time
White Oak*	tree, shrub, vine	Quercus alba	M	FS/PT/SH	unknown	100'	green	--
White Wild Indigo	perennial forb	Baptisia leucantha	M/D	FS/PT	unknown	4'	white	Jun-Jul
Whorled milkweed*	perennial forb	Asclepias verticillata	M/D	FS	no	1'	white	Jun-Aug
Wild Bergamot*	perennial forb	Monarda fistulosa	M/D	FS/PT	no	4'	purple	Jul-Sept
Wild Columbine*	perennial forb	Aquilegia canadensis	M/D	FS/PT/SH	yes	2'	red/yellow	Apr-Jun
Wild Geranium*	perennial forb	Geranium maculatum	M	FS/PT/SH	no	1'	lavender	Apr-Jul
Wild Ginger	perennial forb	Asarum canadense	M	SH	unknown	6"	maroon	Apr-Jun
Wild Hyacinth	perennial forb	Camassia scilloides	W/M	PT/SH	unknown	2'	lavender	May-Jun
Wild Lupine*	perennial forb	Lupinus perennis	D	FS/PT	no	2'	blue	May-Jul
Wild Strawberry*	perennial forb	Fragaria virginiana	M/D	FS/PT/SH	unknown	5"	white	Apr-Jun
Wingstem	perennial forb	Verbesina alternifolia	W/M	FS/PT	unknown	8'	yellow	Jul-Sept
Woodland Phlox	perennial forb	Phlox divaricata	M	PT/SH	no	1'	blue	Apr-Jun
Wool Grass*	grass	Scirpus cyperinus	W	FS	yes	6'	--	--

This table is adapted from the Maumee Valley Growers Native Plant Working Group plant table for Northwest Ohio. For more information refer to **www.maumeevalleygrowers.com/nativeplants.htm**
*Plant native to Oak Openings ecoregion.
**Salt tolerance source: Shaw and Schmidt, 2007

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