Rainwater and Land Development

Ohio's Standards for Stormwater Management Land Development and Urban Stream Protection

***Third Edition 2006**

**Updated to include all new materials, changes and corrections as of 11-6-14.*

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Abstract: Stream systems, including their corridors, and wetland resources are vital environmental features and are extremely sensitive to urbanization. The intent of this book is to allow development to occur while minimizing the impact on water resources, especially streams.

This book defines Ohio's standards and specifications for stormwater practices implemented during land development. It is an update of the previous Rainwater and Land Development book completed in January 1996. The target audience is that group of professionals involved in the design and implementation of development projects.

This book aims to integrate water resource protection into development site planning in order to maintain or improve stream integrity. Early chapters discuss practices and strategies for protecting streams and wetlands, treating stormwater pollutants, rehabilitating streams and establishing permanent runoff controls. The latter portion of the book includes chapters regarding construction-phase practices, including standards and specifications for sediment control, temporary runoff control, soil stabilization and control of pollutants other than sediment. Appendixes offer further information regarding stormwater design examples, permits, helpful contacts, and soils.

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CONTENTS

We want to acknowledge all of the people who deserve credit for helping prepare this significant improvement to Ohio's *Rainwater and Land Development* manual – they were many.

Initially there were the ODNR Division of Soil and Water Conservation's traditional conservation partners: Ohio's soil and water conservation districts, the Ohio Environmental Protection Agency, the USDA Natural Resources Conservation Service and The Ohio State University Extension. Ultimately, many other individuals, representing the development and consulting industry, and local government became involved. They contributed suggestions, photos and content for this manual. Some helped by participating on a Rainwater and Land Development committee or subcommittee, by writing material or perhaps by reviewing drafts as they were developed. All who have contributed their time and efforts have our sincere thanks for their contributions. And we hope all will remain involved in our work to make further improvements in the future. Finally, from within the ODNR, we thank John Mathews for his leadership.

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PREFACE

Rainwater?

When rain falls, runoff supplies and influences Ohio's rivers, creeks and lakes. The land that rainwater encounters and the manner in which it is managed strongly influences the health and integrity of these receiving waters. If we recognize that streams are, in many ways, the most valuable environmental feature of a landscape, how land uses are planned, and how land is developed, becomes critical to continuing the many natural benefits streams provide. The benefits that healthy stream systems provide - water quality services; a natural infrastructure for drainage; a source of biological diversity and environmental productivity - are all diminished if our management of rainwater is inadequate during and after development.

Few activities alter a watershed more or have more potential to permanently lower the quality of streams than urbanization. Historically, the first efforts to offset these impacts focused on strategies controlling peak flow from large, infrequent storm events (i.e., flood control). Concern about the sediment contributed to runoff during construction practices resulted in erosion and sediment control regulations to minimize erosion and capture eroded sediment at construction sites. Experience also showed that historic stormwater controls were not adequately treating runoff.

Urbanization changes watersheds in a multitude of ways, and generic solutions cannot manage all the impacts. Traditional approaches alone fall short of maintaining the integrity of water resources. Success depends on recognizing the characteristics of specific water resources, understanding the relevant impacts, and tailoring a comprehensive array of tools to individual situations. Success requires going beyond a narrow focus on a single problem to undertaking a comprehensive water resource protection strategy. The difference is as great as the difference between rare storms and common rainwater.

Purpose

This book offers a comprehensive source of general standards that can be implemented as land is being developed to avoid, minimize or compensate for impacts to water resources. These practices range from control of specific pollutants, like sediment generated during construction, to practices that help maintain the natural functions of a healthy stream system.

The practices and terminology in this book generally revolve around the movement and dynamics of water. The terms used here should be consistent with hydrologic or engineering usage. A glossary has been provided at the end of this book for terms that are less common or particular to Ohio situations or programs.

Intended Audience

This book should prove most useful to site designers as they attempt to maintain the integrity of Ohio's rivers, creeks and lakes. Additionally local officials, agency staff, planners, and the public will find applications not only to individual sites, but also may assist with land use planning and resource management.

How land is initially developed has tremendous bearing on the prospective quality of urban streams. This material will assist site designers and development plan reviewers in choosing and judging the appropriate practices for a particular site's conditions. Certainly not all the practices in this book are necessary or practical on all sites, therefore site designers must evaluate site conditions and the potential adverse effects of their project on water resources, along with state and local requirements while planning and implementing development projects. Additionally, this book will assist local governments who must determine which issues in addition to site improvements must be addressed to ensure the quality of our water resources.

Authority of this book

In 1979, Ohio's Division of Soil and Water Conservation was charged by Ohio Revised Code (ORC) Chapter 1511 with defining standards to abate erosion and related degradation of the waters of the state. The Natural Resources Conservation Service has a long-standing reputation nationally for defining technically sound standards for conservation practices. Finally Ohio EPA, by ORC Chapter 6111, is responsible for administering the NPDES program to which storm water was added by amendments to the Water Quality Act in 1987. With much input from people in industry, academia, local storm water programs and other states, these three agencies have defined standard practices for the State of Ohio.

The standards themselves are not requirements. In Ohio, responsibility for regulating storm water is held by both local and state authorities. Locally, municipalities, townships and counties all have authority to regulate storm water. Ohio EPA administers the state regulations that require storm water permits for construction sites.

CHAPTER 1

Selecting Stormwater Management Practices for Development Projects

This chapter describes common impacts to prevent as well as the major objectives to apply in order to protect water resources during the development process. Understanding the nature of the impacts prepares site designers to better manage these through alternative site layout and the implementation of practices. Principles utilized during design are provided through stormwater management objectives that also direct designers to the appropriate portions of the manual for applications.

1.1 Adverse Effects of New Development on Water Resources

In order to protect water resource integrity, several impacts must be addressed during development:

- Hydrologic changes of the landscape
- Changes to the drainage network – streams, ditches, swales, waterways
- Increased delivery of warmer, more polluted runoff

Hydrologic Changes

How water is intercepted, stored, used, lost or gained changes substantially after development. Less rainfall is intercepted and utilized by vegetation after development. Less rainfall is infiltrated and percolated into the soils and groundwater following development. And less rainfall is stored in or on top of the ground following storms. All of these hydrologic changes result in more stormwater runoff reaching creeks or rivers faster than before development.

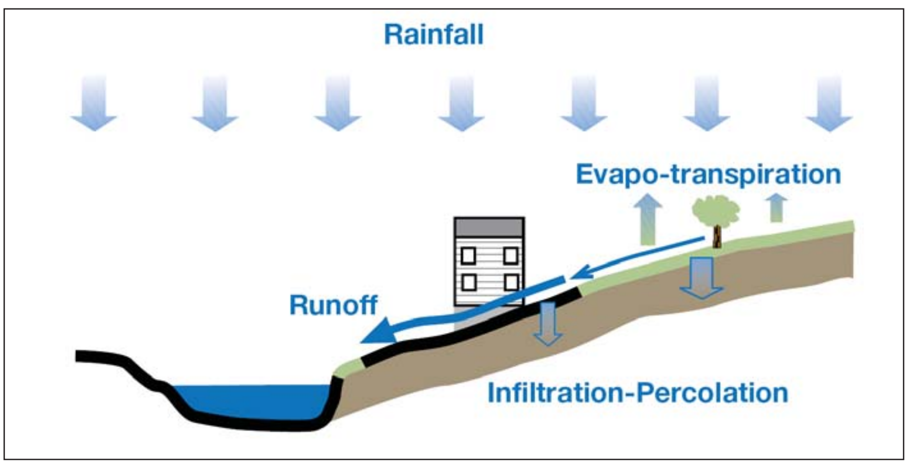
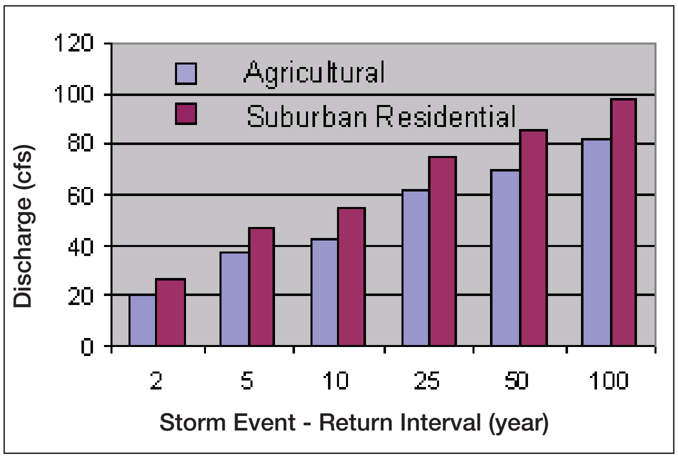


Figure 1.1.1 The hydrologic cycle is altered during urbanization.

The total volume of runoff increases significantly after development as rooftops, roads and hard surfaces replace soil and vegetation. There are other corresponding changes in the hydrology of a developed site. The hardening of a watershed, the compaction of soils, and the direct impacts to streams contribute to them becoming flashier, that is, flows quickly rising and quickly diminishing after each rainfall. Groundwater, normally replenished by percolating rainfall, receives lower levels of recharge in urban areas, affecting both the human and natural communities dependent on groundwater. Wetlands and small streams that require groundwater recharge to sustain them are impacted hydrologically. In its extreme, reduced groundwater recharge, with the subsequent reduction in base flow, may cause former perennially flowing streams to cease flowing during dry periods.

As watersheds urbanize and contribute more runoff, downstream areas experience greater flooding and longer duration flows. It's important to note that even as communities enact flood control strategies, there is still more flow in streams after development that increases flooding and stream erosion.



Storm Event Return Interval (years)	Pre-development Discharge (cfs)	Post-development Discharge (cfs)	Percent Increase
2	21	27	29%
5	37	47	27%
10	43	55	28%
25	61	75	23%
50	70	85	21%
100	82	98	20%

Figure 1.1.2 Stream discharge increases as land use changes from cropped agricultural land to residential using USGS empirical equations for estimating discharge for small urban streams.

To illustrate changes in peak runoff from urbanization, stream discharges were calculated for a typical development site in Eastern Franklin County, Ohio. The peak discharges were estimated for the pre-development condition (agriculture) and the resulting residential development using empirical equations developed by the U.S. Geological Survey (Sherwood, 1986[1]). The table and graph above show the resulting increases in stream discharges. The result was an average 25% increase for the 2, 5, 10, 25, 50 and 100-year return intervals in the estimated peak stream discharges. In water cycle terms, as land urbanizes, significantly less rainfall infiltrates and transpires from vegetation, therefore substantially increasing runoff to streams.

Storm water runoff to this ravine has caused over 2 feet of vertical stream erosion (incision).

Stream Instability and Consequences

As faster and higher stream flows occur on a regular basis, stream channels typically respond by adjusting their shape and size through erosion. Unfortunately, the typical pattern in urban areas is that a healthy stream with a naturally stable form (where bank erosion is balanced by floodplain deposition) becomes physically degraded. The stream cuts downward, losing access to its floodplain and the many functions provided by the floodplain and stream corridor. These deeply entrenched urban streams provide less storage and treatment of stormwater runoff along their corridor than healthy channels. These streams are plagued with bank erosion, contribute more sediment to downstream areas and rarely maintain high quality habitat features such as clean gravel substrates, deep pools and stable riffles. While rehabilitation of degraded streams is possible, the high cost and difficulties associated with working near developed properties makes it critical to prevent these problems in the first place. It makes sound economic and ecological sense.

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[1] Sherwood, J.M. 1986. *Estimating Peak Discharge, Flood Volumes, and Hydrograph Shapes of Small Ungaged Urban Streams in Ohio*. USGS Water Resources Investigation Report 86-4197, 52 pp.

Stream instability associated with stormwater increases often brings hard and harsh solutions.

Thermal, Biological and Chemical Pollution

Increased development results in more pollutants and in more runoff, with the result that the pollutant loading from each storm event is markedly higher after development. Development also reduces the watershed's natural treatment (assimilation) as runoff speeds toward the stormwater system and streams without opportunity to soak into soils. The chemical quality of urban runoff is diminished as concentrations of suspended fine sediments, nutrients, oxygen-demanding materials, bacteria, heavy metals and hydrocarbons from oil and gas, pesticides, chlorides from road salt increase. Urban runoff has been shown to have pollutant concentrations similar to sanitary wastewater. Unfortunately stormwater systems traditionally have been designed so that these constituents – once in runoff – have little opportunity to be removed before reaching a lake, creek or river.

Numerous pollutants of concern are concentrated in urban runoff and urban stream systems. Hydrocarbons, associated with petroleum products, concentrate in high traffic areas and concentrate in sediments of urban streams. A California study also found sediments in urban streams had 3 to 10 times more heavy metals than non-urban stream. The United States Geological Survey has sampled urban runoff, and commonly found herbicides, high phosphorus levels, and fecal coliform in concentrations that exceed recommendations for water contact.

The temperature of runoff from urban land uses is much higher than normal stream flow and increases the threat to stream life. Fewer trees along urban creeks often compound the problem by allowing sunlight to warm the water surface. High temperatures stress aquatic organisms by pushing them towards or beyond their temperature tolerances in warmer seasons and by lowering the oxygen-holding capacity in the water. Often the low amount of dissolved oxygen in urban stormwater is indicated by a sewer-like smell.

Summary of Urban Water Resource Problems Related to Development:

- Increased pollutant availability
- Increased runoff
- Increased peak flows and stream “flashiness”
- Stream Instability
- Decreased stream function in incised and modified channels
- Decreased storage and treatment of stormwater along stream channels
- Increased stream temperature
- Decreased groundwater recharge
- Decreased baseflow for streams and wetlands
- Less natural pollutant assimilation in soils
- Diminished aquatic life

Urbanization and Stream Decline

Studies indicate that even at low levels of urbanization (5-10% imperviousness) stream ecosystems begin to rapidly decline (Schueler, 1994[2]). These urban streams lose much of their biological diversity, leaving only populations of pollution tolerant species. A study[3] by the Ohio Environmental Protection Agency of 110 urban sites found poor or very poor scores at the majority of the urban impacted sites (85%). More than 40% of suburban sites were impaired with many reflecting the negative impacts of new developments for housing and commercial uses. As this study stated, "The results demonstrate the degree of degradation which exists in most small urban Ohio watersheds and the difficulties involved in dealing with these multiple and diffuse sources of stress."

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[2] Schueler, T. 1994. The Importance of Imperviousness. *Watershed Protection Techniques.* 1(3): 100-111.

[3] Yoder, C.O. and E.T. Rankin. 1996. Assessing the condition and status of aquatic life designated uses in urban and suburban watersheds, pp. 201-227. in Roesner, L.A. (ed.). Effects of Watershed Development and Management on Aquatic Ecosystems, American Society of Civil Engineers, New York, NY.

1.2 Stormwater Management Objectives for Development

This section presents stormwater objectives a site developer must address in planning and designing a development project which protects water resource integrity, along with the specific management practices available for addressing these objectives, and the appropriate chapter in this manual where guidance about these practices may be found.

1. Preserve the natural drainage system and important water resources

The natural drainage system that exists prior to development provides many benefits ranging from stormwater management and drainage services, to natural pollutant removal and wildlife habitat. For this reason, designers must preserve as much of the existing stream system as possible, by preserving streams, their corridors (streamways) and wetlands and by minimizing the extent that storm drains and constructed ditches replace natural drainage ways. Even open swales and ephemeral drainage without well-defined channels provide valuable stormwater benefits and should be preserved where possible.

Developments that build too close to watercourses may cause significant problems after the property is occupied since:

- structures on active floodplain areas may be damaged by flooding
- loss of natural floodplains increases flooding and pollutant loads, and decreases natural stream stability elsewhere along streams
- property or infrastructure may be damaged by natural stream migration or movement (meandering), or the elevated groundwater associated with saturated floodplains or wetlands
- stream integrity may be degraded due to the loss of the natural riparian corridor

For these reasons, this manual strongly encourages site designers to begin site layout by defining the existing drainage system, an adequate stream corridor, and floodplains based on the projected built out conditions in the watershed. The following management practices in Chapter 2 and additional resources will help achieve this objective:

• Wetland Setbacks	Chapter 2, Page 15
• Stream Setbacks	Chapter 2, Page 21
• Stream and wetland permitting	Appendix 2

2. Minimize imperviousness of the proposed development

Minimizing imperviousness must be a major objective during site layout. Numerous studies show that increases in pollutant loads, runoff volumes, and peak discharge rates are directly related to increases in the impervious areas within a watershed or project area. The greatest opportunity to reduce imperviousness lays in the sizing and layout of streets and parking areas. Parking standards traditionally have promoted having excess parking even during peak use. Some communities have begun to modify parking requirements to reflect stormwater concerns. Where building regulations and zoning allow, options such as reduced parking ratios or shared parking, clustered development reduce total site imperviousness and often reduce development costs.

Streets should be designed for the minimum pavement area to support the uses and the traffic based on the expected volume of traffic and the access needed. Alternative residential street layouts that maximize the number of homes per length of street also help reduce overall imperviousness. In commercial development, separating frequently utilized parking areas from rarely used areas provides an opportunity to use alternative parking materials such as modular pavers that reduce runoff and allow some infiltration in low use areas. Even without changing ordinances and development regulations, site designers have potential to reduce excess imperviousness by not exceeding minimum standards and utilizing shared parking between compatible uses, and variances may be an option. Of course, the area not used for parking must be replaced with open space or landscaping, not with other impervious surfaces.

Where hard surfaces cannot be reduced for development goals to be achieved, it may be possible to "disconnect" impervious surfaces from the drainage system and provide opportunities for runoff from small storms to percolate into the soil.

The following management practices in Chapter 2 may be used to achieve this objective:

- Low Impact Development — Chapter 2, Page 3
- Impervious Area Reductions — Chapter 2, Page 5
- Conservation Subdivision Design Principles — Chapter 2, Page 11

3. Improve degraded streams

In many cases, a watercourse through or adjacent to a development project has been degraded by past land uses and/or upstream development. Occasionally a developer may be relocating portions of a degraded watercourse during development. Developers may also be required to restore watercourses to mitigate for on-site impacts. In other cases, eroding channels may need special measures to prevent further degradation that can be more easily addressed during development or can prevent substantial future property loss.

In any of these cases, guidance in Chapter 3 can be used to address issues of degraded stream resources. Ultimately, by promoting or maintaining the naturally sustainable functions of these streams, many valuable stormwater management and water quality services will be provided via functional streams in addition to those provided through the still critical individual best management practices. Protection and restoration of floodplain and stream resources provide benefits of sediment reduction, nutrient removal and higher quality stream habitats. Restoration and rehabilitation of streams is best accomplished before or during development, since there are fewer impediments regarding stream access, and movement of materials and equipment. Costs increase and managing restoration/rehabilitation projects become more difficult as the area around the stream becomes more developed. Other issues such as the use of soil from previously filled floodplains can be more easily solved if coordinated with the site development plans.

The practices and reference materials in Chapter 3 and Appendix 7 may be used to address unstable and degraded streams.

4. Plan additions to the site drainage system that are stable and sustainable

Often the changes in runoff that occur during development will subject some areas, such as existing swales or watercourses to increased erosion. Areas of particular concern on developed sites include outlets from storm sewers and detention facilities, open drainage ways, areas receiving concentrated flow, and slopes.

Chapter 4 of this manual provides guidance on permanent runoff controls that typically must be installed during development to convey runoff and prevent accelerated erosion.

5. Manage post-construction runoff

Nearly every development project will require measures to control the impacts of increased runoff from the project. Those impacts include:

- Higher peak discharges
- Increased runoff volume
- Accelerated flow velocity
- Elevated pollutant loading

An effective system of stormwater runoff controls will address the increased energy and frequency of peak flows, as well as the increased pollutant load in the runoff. These controls must be in place throughout the watershed to address the cumulative impacts of urban land uses on stream stability, downstream flooding and water quality.

Stormwater management practices typically perform multiple functions including flood control, pollutant removal, and reducing downstream erosion potential. Stormwater practices can be integrated into the landscaping, drainage network, and other open spaces of development projects. Properly designed they can become amenities rather than impediments to development projects.

Chapter 2 and Appendix 1 provide guidance on the design, construction, and maintenance of the most common stormwater management practices that incorporate water quality and stream protection applications. The control practices described have: a proven performance track record, wide applicability within Ohio, and extensive resources available about their design, construction, and maintenance. Alternative measures are evolving but should be considered only if extensive data and justification can be presented to support their proper design and long-term performance.

The following management practices in Chapter 2 may be used to achieve this objective:

• Water Quality Ponds	Page 2-27
• Infiltration Trench	Page 2-41
• Sand Filter	Page 2-49
• Grass Filter	Page 2-63
• Bioretention Area	Page 2-69

6. Control erosion and sediment impacts during construction

Construction and associated earthmoving activities cause high sediment loads in construction site runoff. Planning for these controls begins during site layout, with overall sediment and erosion control strategies developed during the final phases of project design. While implementation of construction-phase controls is left to the contractor, they must be guided by the strategies specified by the site designer in construction plans.

Chapters 5 *(Temporary Runoff Controls)*, 6 *(Sediment Controls)*, 7 *(Stabilization Controls)* and 8 *(Additional Construction Site Pollution Prevention and Small Construction Site Controls)* of this manual describe the appropriate controls for construction phase impacts. Chapter 5 shows practices that direct muddy runoff toward sediment controls, manage runoff in order to prevent erosion and allow stable crossing of streams. Sediment control practices from Chapter 6 are utilized to remove sediments from runoff before it leaves the construction site. Effectively establishing vegetative cover on disturbed areas is the focus of Chapter 7, Stabilization Controls. This chapter also describes dust control, limiting soil disturbance and methods of temporary stabilization. Chapter 8 describes how small building lots can provide erosion and sediment control and handling of additional sources of pollutants, such as fuels and construction materials.

7. Control high risk pollution sources

Chapter 8 *(Additional Construction Site Pollution Prevention)* gives descriptions of non-sediment pollution concerns existing on construction sites and other state requirements for these as well as management recommendations. Some land uses such as industrial areas may have a high risk of releasing pollutants and may not have appropriate practices described here. Most of the stormwater management measures described in chapter 2 of this manual are not appropriate for treating pollutants from: material and waste storage and handling; vehicle fueling and service; equipment cleaning areas or other areas that contain pollutant concentrations significantly higher than typical urban runoff. Runoff from these activities should be segregated from other site runoff and directed to more advanced treatment options such as oil-water separators, containment systems, or sanitary sewers. Alternatively, areas where these activities occur could be covered and/or moved indoors.

U.S. EPA and Ohio EPA offer additional information regarding safe material storage, containment and pollution prevention practices in their NPDES permit program materials regarding pollution prevention and good housekeeping for municipal operations.

8. Assure long-term access to and maintenance of stormwater system

Regular inspection and maintenance of stormwater controls are necessary if these controls are to consistently perform up to expectations. Developers and municipalities must address these issues during project design. Facilities that are inaccessible and/or lack features to facilitate maintenance will become a nuisance. A reliable party with adequate funding to perform maintenance is essential – many communities that have overly relied upon property owners, homeowners associations, and similar parties to perform maintenance have ultimately had to assume these responsibilities, often at a much higher cost than if the facility design and institutional arrangement had been established at project inception.

Suggested maintenance practices are included with each control measure in this manual.

CHAPTER 2

Post Construction
Stormwater Management Practices

Post-construction stormwater management practices treat runoff from a development site *after* construction is complete. Their objectives range from capturing and treating pollutants in runoff to managing the increased frequency, volume and energy of stormwater runoff so that water resources are not degraded.

Historically, stormwater ponds were used to reduce downstream flooding. Today post-construction stormwater ponds add pollution control and stream protection as important design elements. Apply the structural practices found in this chapter to reduce pollutants, meet state and local permits and reduce downstream erosive effects of runoff. While all structural practices require maintenance, those provided here emphasize lower maintenance and generally self-sustaining processes. Other structural practices are available for use; yet all should be examined for their effectiveness, maintenance requirements and ability to function if maintenance is delayed.

Treatment occurs primarily through the processes of settling, adsorption, and biological uptake, while detention is utilized to curb the impact of increased runoff. Where soils are appropriate, infiltration provides substantial hydrologic benefits.

Structural practices treat runoff, but more is needed to effectively prevent and minimize impacts. Therefore additional management practices are strongly encouraged. Practices such as stream setbacks or reduction of impervious areas influence the layout and design of a development site so that important hydrologic areas are maintained and runoff is limited. Many of the management practices provided have more exhaustive reference sources given that should be consulted as they are applied. Note that while each of the management practices is beneficial, some community zoning or building standards may limit your ability to use a particular practice.

MANAGEMENT PRACTICES

STRUCTURAL PRACTICES

2.1 Reduction of Impervious Areas

Description

Impervious area is the largest cause of increased stormwater runoff as a result of development. Any type of surface that does not allow water to penetrate it is considered impervious. Impervious areas do not allow precipitation to infiltrate into the ground or be absorbed by vegetation, thus increasing the quantity of stormwater runoff and all of its associated problems. Impervious areas consist of asphalt or concrete used in roads, parking lots, drive ways, sidewalks and roofs.

Condition Where Practice Applies

Almost every development project includes the construction of some type of impervious surface, which will contribute to the increase in stormwater runoff. Opportunities to reduce the amount of impervious area exist on practically every project.

Planning Considerations

Although the developers have the ability to incorporate alternative designs that reduce the amount of impervious area in their project, it is the local-governmental agency(ies) that will actually determine what can and will be used. It is in the best interest of communities to allow some alternative design options, especially with Phase II stormwater regulations.

- Parking Lots

  Local community officials may change or modify the zoning ordinance pertaining to parking lots. The number of required parking spaces can be reduced.

"Green space" can be added to or increased within the parking lot. Additional overflow parking can utilize non-paved areas. The minimum number of trees required in parking lots can be increased. Some types of grass reinforcement can be used to provide maintenance and emergency access instead of traditional hard surfaces.

- Decrease Pavement Connectivity

  Another proven method to reduce and slow down stormwater runoff is to provide breaks in the connectivity of pavement. Instead of having large paved areas, provide a grass area for water to flow to and then into the storm sewer system. This slows down runoff, and provides other environmental benefits.

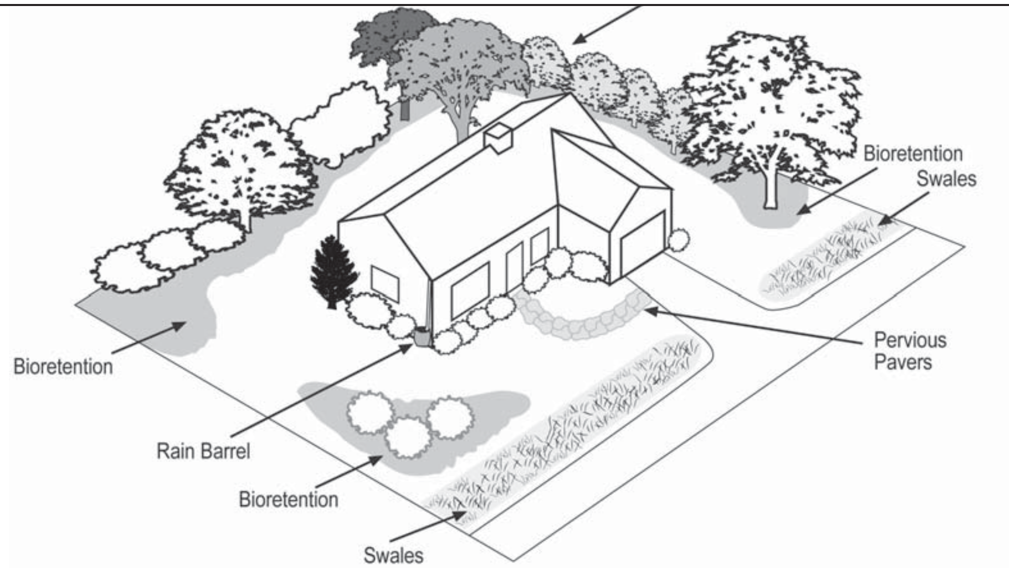
- Sidewalks

  The width of sidewalks may be reduced to reduce the amount of impervious area. Or some type of stepping stones can be used as a walk way. Pavers with permeable bases allow water to infiltrate between the individual stones, instead of increasing runoff.

- Buildings

  Buildings can also be designed to reduce the amount of impervious area. Instead of having a large floor plan, buildings can be built higher reducing the amount of impervious area added by its roof. The amount of runoff created by its roof can be reduced by using a "green" roof. These are typically planted with grass, ground cover, and even small trees and bushes. They are very popular in large cities where land is not available. Green rooftops can serve as a park-like setting open to the people in the building. They may also be used solely to provide stormwater benefits. However, if there is flexibility in the local and state codes that permit green roofs, few developers will proceed with the concept. Once again it would be in the community's best interest to include green roofs as an acceptable design alternative in their standards.

2.2 Low Impact Development



Description

Low-impact development (LID) is a site design approach, which seeks to integrate hydrologically functional design with pollution prevention measures to compensate for land development impacts on hydrology and water quality. LID's goal is to mimic natural hydrology and processes by using small-scale, decentralized practices that infiltrate, evaporate, detain, and transpire stormwater. LID stormwater controls are uniformly and strategically located throughout the site.

LID is achieved by:

- Minimizing stormwater runoff impacts to the extent practicable through preservation of existing landscape features and their hydrologic functions.
- Maintaining predevelopment time of concentration through strategic routing of flows using a variety of site design techniques.
- Dispersing runoff storage measures through a site's landscape through the use of a variety of detention, retention, and runoff practices.

LID practices manage stormwater at its source. LID measures reduce impervious cover, minimize disturbance, preserve and recreate natural landscape features, increase hydrologic disconnects and facilitate infiltration and detention opportunities. LID creates a multifunctional landscape which relies on natural features and processes and emphasizes simple, nonstructural, low-tech methods.

Conditions Where Practice Applies

LID can be used in a broad range of land use situations. Due to maintenance considerations, LID may be most appropriately utilized on institutional, industrial, commercial and governmental developments. However, LID in tandem with conventional stormwater control features can be successfully integrated into any development. LID has been demonstrated to work in new developments and constrained sites involving urban infill or retrofit to reduce combined storm sewer inflows.

Planning Considerations

LID is a design approach and represents a collection of stormwater management practices that may be utilized together to manage stormwater. LID measures are often used as a supplement to conventional stormwater practices to meet the state critical storm criteria and provides post construction water quality benefits.

Nine steps in the LID Site Planning Process.

1. Determine the applicable zoning, land use, and subdivision regulations,
2. Define development envelope (total areas that affect hydrology on site),
3. Use drainage/hydrology as a design element,
4. Reduce total site impervious areas,
5. Integrate preliminary site layout plan,
6. Minimize directly connected impervious areas,
7. Modify/increase drainage flow patterns,
8. Compare pre and post development hydrology and identify Integrated Management Practices (IMP's),
9. Complete LID site plan.

The LID principals are designed to minimize disturbance and manage the stormwater as close to its source as possible. Specific low impact development controls called Integrated Management Practices (IMP's) are tools for developers to utilize to manage stormwater at its source rather than relying solely on centralized BMP's such as detention basins. Common IMP's are detailed below under Design Criteria. Each IMP will have specific planning considerations; however the following details several of the common planning considerations.

- **Clay Soils:** Higher proportions of clay particles in the soil (greater than 27%) will reduce the effectiveness of infiltration-based measures and require greater use of surface depression measures.
- **High Water Table:** High water table, even high seasonal water tables, may restrict the use of some IMP's. Provide at least 2 to 4 feet of separation between the bottom of the IMP 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:** IMPs should not be located near foundations of buildings or other structures.
- **Deed Restrictions:** Maintaining distributed depression storage measures within residential subdivisions will require deed restrictions on individual parcels as well as homeowner education programs to ensure measures are maintained.

- **Zoning Variances:** Variances from zoning, subdivision, building, stormwater management, and drainage regulations may be required unless LID is permitted.
- **Snow:** Snowbelt areas of Ohio may find that parking lot LID measures will need to consider snow storage and the effects of road salt on plant material.
- **Design Costs:** Up-front design costs may increase over design of conventional stormwater management approaches due to the need to "fingerprint" the site and complete microscale design of the integrated management practices. However, construction and maintenance costs often decrease.
- **Public Health:** Public health concerns exist about West Nile Virus and other mosquito borne diseases. Brackish water pools may serve as the breeding ground for the mosquitos that carry West Nile Virus. Proper design and construction of stormwater management facilities are necessary to minimize or eliminate this issue.
- **Maintenance Access:** Easements may be necessary to give the community access for maintenance on IMPs.
- **Contractor Guarantees:** Obtaining contractor guarantees for some integrated management measures may not be possible due to lack of standard construction and material specifications.
- **Public Education:** Public education materials are essential for long term management of IMP's.

LID is a relatively new approach to stormwater management in the U.S and has not been used extensively in Ohio because of historic focus on water quality control, climatic factors, lack of regional design standards and cost. However, many of the IMPs, including bioretention, vegetated swales, filter strips and porous pavers, have been utilized individually. LID may also be an important tool to reduce the effects of land use changes near ecological sensitive areas.

Design Criteria

The goal of LID is to mimic the predevelopment hydrology through runoff volume control, peak runoff rate control, flow frequency/duration control, and water quality control. To effectively manage stormwater using LID, the developer must define the hydrologic control (runoff, groundwater recharge, infiltration), evaluate the site constraints (slopes, soils), evaluate and select IMP's that are appropriate considering the hydrologic scheme and site constraints. The addition of some conventional controls may be necessary to complete the stormwater management scheme for the developed site.

See other sections of the Rainwater and Land Development Manual for applicable design criteria on grassy swales, and bioretention. There is no limit to the number of IMP's which may be implemented as part of a low impact development.

Some additional integrated management practices include:

- Biofiltration
- Dry Wells
- Filter/Buffer Strips
- Vegetated Swales
- Cistern & Rain Barrels
- Infiltration Trench
- Green Roof
- Wetland Channels
- Soil Amendment
- Impervious Surface Reduction

Pervious Paver installation

Bioretention

Maintenance

LID may be most appropriately used in institutional, industrial, commercial and governmental developments, as these facilities are more likely than residential developments to receive maintenance on LID features over residential developments. When maintenance is required, additional easements may be necessary to facilitate maintenance access. In residential developments the landowners or homeowners association are often responsible for any required maintenance. Regular inspections, by or for the responsible party, must be completed to ensure LID and conventional stormwater control features continue to operate properly.

Plans and Specifications

See other sections of the Rainwater and Land Development or the resources below for applicable specifications for integrative management measures.

References

Natural Resources Defense Council. 2001. NRDC's Storm Water Strategies (CD-ROM). Washington, D.C.

Prince George's County. 2000. Low-Impact Development Design Strategies: An Integrated Design Approach. Department of Environmental Resources, Maryland.

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SCS. 1985. National Engineering Handbook. Section 4 Hydrology (NEH-4). U.S. Department of Agriculture, Washington, D.C.

SCS. 1986. Urban Hydrology for Small Watersheds. Technical Release 55. U.S. Department of Agriculture, Soil Conservation Service, Engineering Division, Washington, D.C.

Tyne, Ron. 2000. Bridging the Gap: Developers Can See Green Land Development. Spring/Summer 2000: 27-31.

Web Site References

Low Impact Development, Urban Design Tools http://www.lid-stormwater.net/

Low Impact Development Center http://www.lowimpactdevelopment.org/

U.S. EPA http://www.epa.gov/owow/nps/urban.html

Prince George's County, Maryland http://www.goprincegeorgescounty.com

NAHB Research Center Toolbase Services http://www.toolbase.org/

2.3 Conservation Development

Photo by Kirby Date

Description

Conservation Development refers to development practices that allow land to be developed while conserving a sense of rural character, protecting natural resource features, and insuring water quality. In the process, property rights are protected, the community retains its unique identity and resources, the developer benefits with a high-quality project, and the environmental impacts of development are reduced.

Conservation Development typically allows higher density on a portion of the site in order to leave the rest of the site undeveloped. This results in the same number of structures that would be allowed in a traditional development on a particular parcel of land being located with more flexibility while requiring that a substantial (over 40%) of the land be set aside as permanent open space. The resulting protected open space provides room for conservation practices that serve to buffer the impacts of the development. The conservation practices selected and used can:

1. Reduce stormwater flow through retention and detention basins.
2. Reduce impervious surface area.
3. Increase the filtering of stormwater runoff.
4. Reduce heat reflectance.
5. Retain the original vegetation.
6. Retain historic structures.
7. Allow for the continuation of economically viable agriculture.
8. Allow for the protection of other environmental benefits.

Conservation Development vs. Low Impact Development

Conservation Developments should not be confused with Low Impact Developments. The basic difference is:

- **Conservation Development** involves the overall layout of the property to retain open space. It may or may not include Low Impact Development measures in its site plan.
- **The Low Impact Development** concept applies to how a development is laid out with on-site measures being taken for stormwater retention and management. Low Impact Developments are discussed earlier in this section of the manual.

Conditions Where Practice Applies

This concept is appropriate in all communities regardless of its current development pattern. Each community, large or small, can use the Conservation Development concept as it develops current open space and redevelops existing built-up areas.

Planning and Design Criteria

Ultimately, communities meeting with the most success at achieving a balance of conservation and development will be those that implement a range of tools for different zoning purposes. Outright purchase, use of conservation easements, purchase of development rights, and conservation zoning are all examples of tools that communities can use for land preservation. Each tool has a different set of circumstances under which it works best; and each community will have a unique set of situations of which it can take advantage. Conservation Development techniques are implemented at the planning, zoning and project levels to soften the impact of development on community resources. Conservation Development is one of several tools communities should utilize if they desire to achieve a balance of Conservation and Development that is critical to their long-term quality of life.

Conservation Development vs. Conventional Development

Conventional development patterns result in uniformity despite differences in terrain, climate or site features. Much of this is the result of uniform zoning standards dating to the 1940s. Many of these codes also required practices that are damaging to the rural and natural environment. For example, wide road pavements multiply stormwater problems through increased impervious area and flow-concentrating curb and gutter systems that often send large quantities of untreated stormwater into local streams.

Applying conservation development concepts to a development site utilizes the uniqueness of each site. By preserving significant areas of open space, original woodlands, wetlands, or stream corridors, the site maintains natural and cultural values. Some agricultural uses can be continued; rock outcroppings, old barns, heritage trees, and windrows can be focal points. Open space areas also serve to reduce stormwater runoff and improve its quality. Conservation developments also provide the flexibility to buffer views of development from the road, retaining a sense of openness.

A Typical Conservation Development Project

1. Decisions on site layout and character depend upon the land itself, the community in which it is located, and the intended market of the project. While each conservation development project is unique, there are several characteristics common to most projects.
2. Flexible lot layouts: Within a development, the permitted number of structures are placed on somewhat smaller lots, and the remaining land is set aside as open space. For example, providing one acre lot sizes in a two acre zoned area allows half the land to be preserved.
3. Retain significant amounts of open space: Forty percent (40%) of land area or greater is retained in large, contiguous parcels appropriate to the conservation objective for the area - whether it is a stream corridor, a hillside meadow, a woodland, or farmland.
4. Competitive economic return to property owner and developer: Studies have shown that homes in Conservation Development subdivisions sell for the same, or even greater value and appreciate faster than homes in comparable traditional layouts. This is associated with each home's view and access to permanent open space.
5. Open space is retained permanently in private ownership: Typically these projects have a properly structured homeowners association conservation easement agreement, which includes legal and financial provisions to ensure preservation of open space and to secure its management and maintenance. Usually, the homeowners' association retains ownership and maintenance responsibilities; a conservation easement dedicated to a third party conservation organization ensures the land will not be developed.
6. Retention of rural character: Large open space acreage allows flexibility to buffer views of the development from the road, and to preserve historic structures and landscapes.
7. Reduced length and size of roads and utilities: Sometimes private roads and shared driveways are provided. This aspect is a benefit both to the community, which has less to maintain, and the developer, who has less to build. Environmental impacts related to increased impervious surfaces are reduced. Consideration needs to be made for police, fire and other public vehicles that need to use the road.
8. Alternative septic/sewer arrangements: Areas without urban sewer and water sources may be restricted to lots of a size that support a septic leach field. Alternatives are being explored which should yield lot-reduction options over time. In the meantime, areas in which the zoned lot size is larger than the minimum required for septic leach fields have potential for flexible zoning. For example, areas zoned 3 acres may reduce lot sizes to the 2 acres required by a county health department, and retain 33% of the land in permanent open space. Consultation needs to be made with the local health department for regulations pertaining to septic/sewer arrangements.
9. Commercial development projects also have an emphasis on compatibility with rural aesthetics, reduction of pavement and other impervious surfaces, and providing a community enhancing experience for the customer and passerby.

10. Conservation Easements: A conservation easement is a legal agreement where some of the property rights are transferred from the landowner to an organization that is dedicated to protecting the land rights being transferred. This allows the landowner to continue to own and use the land and sell it or pass it on to heirs while permanently protecting the land. Future landowners are bound by the agreement and the conservation easement holder is responsible for making sure that the agreement is upheld. Conservation easements are discussed in the appendix of this manual.

Steps To Conservation Development in Your Community:

1. Comprehensive Plan: Identify important natural, agricultural and cultural resources, and the priorities for conservation on a site or in the community. Determine, based on these priorities and resources, which of the above planning and development tools will be appropriate for conservation of each area or natural resource. Conservation development is applied best where surrounding open space and development is suitable.

2. Evaluate your zoning code: Make sure the zoning codes will help and not hinder your purpose. The overall comprehensive plan should have codes that correspond and help to implement it. Adopt code change to encourage the kind of development identified as a priority in the comprehensive plan.

3. Encourage quality development projects: The best projects result from a cooperative atmosphere, with developers and community members working together in both design and construction. Identify the developers in your community, discuss some of these ideas with them, and see how you can work together to create exemplary projects that will be an asset to your community.

Reference

For additional resources contact:

The Countryside Program
Kirby Date, Director
P.O. Box 24825
Lyndhurst, Ohio 44124
Phone: 216.295.0511 fax: 216.295.0527
http://www.countrysideprogram.org/main_frameset.html

"The Countryside Program Resource Manual" by the Countryside Program, a project of the Western Reserve Resource Conservation and Development Area. P.O. Box 24825, Lyndhurst OH 44124

2.4 Wetland Setback

Description

Wetland Setbacks are areas retained around existing or created wetlands in order to protect the natural functions of the wetland. Wetland Setbacks left in or restored to a "natural" vegetated state provide an enhanced level of wetland protection not currently afforded by state and federal wetland regulations.

This practice recognizes the valuable services that wetlands provide, while acknowledging that these wetlands have been formed under conditions of less stormwater pollution and imperviousness. Wetland Setbacks reduce wetland degradation associated with development by treating surface runoff for pollutants, transferring surface runoff to subsurface flow and providing a vegetated buffer from more intensive landuses.

By maintaining functional wetlands within their community, local governments and landowners ensure that the natural services provided by wetlands are not lost or transferred out of their watershed.

Conditions Where Practice Applies

Wetland Setbacks are appropriate on all lands surrounding wetlands which receive run-off from development or redevelopment areas. Wetland Setbacks can be utilized in a low impact or conservation development design plan, as part of the regulatory permitting process or normal site design planning. Wetland Setbacks may be most appropriate on those wetlands that are hydrologically connected to other water sources such as springs or streams.

Wetland Setbacks are an appropriate best management practice in a community's Storm Water Program (e.g., NPDES Phase II) or as part of their land use planning. Wetland Setbacks can be incorporated into local zoning codes.

Wetland Setbacks are applicable where the site designer has the objective of mimicking the predevelopment hydrology, reducing the amount of stormwater and maintaining natural features. Establishing wetland setbacks and the associated protection of wetland resources may also be used to demonstrate avoidance of impacts as part of a wetland permitting process.

Wetland Setbacks are also appropriate for ponds, lakes and Water Quality Ponds; however, these features may need to have maintenance access incorporated into any setback area.

Wetland Definition and Value

Generally, wetlands are those areas near streams and in uplands that are inundated or saturated by enough water to be dominated by vegetation adapted for life in saturated soil. In Ohio, wetlands include swamps, marshes, fens, bogs and similar areas.

Wetlands are legally defined in section 40 Code of Federal Regulations (CFR) 232. The U.S. Army Corps of Engineers also has specific regulations covering activities in wetlands as well as technical guidance on determining the extent of wetlands.

Wetlands provide a variety of services to communities and landowners, including:

- **Flood Control:** Wetlands reduce peak flood flows, store floodwaters, and maintain stream base flows.
- **Erosion Control:** Wetlands minimize stream bank and bed erosion by regulating water volume and velocity. Note: natural wetlands are not to be utilized for construction site runoff control.
- **Ground Water Protection:** Wetlands minimize impacts on ground water quality by filtering pollutants from stormwater runoff. Many wetlands recharge ground water reserves.
- **Surface Water Protection:** Wetlands minimize impacts on surface water quality by reducing sediment pollution from stream bank erosion, and by trapping sediments, chemicals, salts and other pollutants from runoff.
- **Habitat:** Wetlands provide essential habitat, particularly for nesting and breeding for many aquatic and terrestrial organisms.

Planning Considerations

Existing Local Requirements

Some counties, townships and municipalities across Ohio have already adopted wetland setbacks. In the event that these setbacks differ from those described here, the larger of these requirements should be used.

Adjustments to the Setback Width

The **setback widths** given in this practice offer minimum protection and should be considered for expansion if any of the following conditions apply:

- Areas crucial to the hydrology of the wetland such as springs, floodplains or streams extend beyond the standard wetland setback. These areas should be considered for incorporation in the setback area, since maintaining the hydrologic support for the wetland is critical to its continuing function.
- The wetland is a rare, sensitive or high value wetland system. These systems need greater buffer widths to ensure protection of the current quality.
- Habitat protection, either of wetland species or species that utilize the wetland, is a major objective. Greater than 100 feet is recommended, but wildlife expertise may be necessary to determine the conditions and width needed for the particular species.
- Larger setbacks may be appropriate for drainage from a commercial or industrial facility that may require pretreatment and flow attenuation.
- Areas that are steep or sparsely vegetated will have lower effectiveness in providing water quality protection for adjacent wetlands and therefore should be expanded.

Storm water management and site planning needed in addition to setbacks

Wetland setbacks will help protect wetland systems, but more is needed as development occurs. Storm water controls will still be needed to control high-energy flows and to mitigate for increased pollution.

Encourage wetland protection through community support and planning

Wetland setbacks are a tool that can be used to protect water quality and water resources. Local planning officials should consider how to facilitate wetland setbacks through wetland identification tools (soils, wetland and land use maps), landowner assistance, zoning code and land acquisition.

Utilizing publicly available resources to produce planning or land use maps can help communities identify where wetlands and wetland setbacks are most likely to be applied. The Natural Resource Conservation Service and the local Soil and Water Conservation District provide soils maps and a list of hydric soils. National Wetlands Inventory (U.S. Fish and Wildlife Service) and Ohio Wetlands Inventory (Ohio DNR) maps may also be useful in finding wetland locations for planning purposes. Note these maps are not appropriate for making wetland delineations. Wetland delineation information is available from the Ohio EPA and the U.S. Army Corps of Engineers.

Finally protect wetland setbacks and the wetlands they surround by placing these areas under a conservation easement. Note that deed restrictions are much less protective since a judge can abolish them at the request of a landowner without public notice.

Landowner Assistance

Several publicly funded organizations are available to assist interested landowners in managing wetlands on their properties, including:

- Soil and water conservation districts,
- Natural Resource Conservation Service
- Ohio Environmental Protection Agency
- Ohio Department of Natural Resources, and
- Ohio State University Extension Service.

These organizations can advise landowners on what to plant near wetlands, where to locate soil disturbing activities to minimize short and long term damage to these services, and any applicable local, state, or federal regulations that may apply to an activity the landowner wishes to undertake. The Ohio Environmental Protection Agency (Ohio EPA) and the U.S. Army Corps of Engineers are available to assist landowners in understanding specific regulations that may apply to proposed activities.

Communities can facilitate wetland setbacks and other wetland management by connecting interested landowners to available county, state, and federal conservation services. A list of conservation agencies is available in the Appendix Section. Conservation funding may be available for purchase of easements or for public land acquisition.

Land Acquisition

Communities may acquire properties that include wetlands that are providing flood control, erosion control, water quality protection, or habitat services either through direct purchase of land, conservation easements, or some other form of permanent preservation. This approach is appealing to communities because it is non-regulatory and enables direct community control over local wetland resources.

Incorporating Wetland Setbacks into Zoning

Zoning regulations that direct the location of development away from wetlands must detail the public health and safety functions of the community's wetlands including flood control, erosion control, and water quality protection, and must be built on technical information supporting these services from the lands being regulated.

Zoning for Wetland Setbacks, unlike landowner assistance or land acquisition, allows communities to directly influence the location of new development and redevelopment. The goal of any zoning code that incorporates Wetland Setbacks is to ensure lots remain buildable and subdivision lot yields are maintained to the extent possible, while pulling soil-disturbing activities back from wetland areas. Thus zoning setbacks should be flexible incorporated to allow variances to other zoning setbacks, such as front and side yard setbacks, to allow site designers to maintain development lot yields. The disadvantages of implementing Wetland Setbacks through zoning controls are that it is an additional regulation and requires community staff to develop and implement.

Regional planning agencies and watershed organizations may also be able to offer assistance in establishing local ordinances and resolutions that maintain wetlands within developing communities.

Permitting For Wetland Impacts

In Ohio, the regulatory permits required to impact "Waters of the State," including lakes, wetlands and streams, may involve both the Army Corps of Engineers (Corps) and Ohio EPA through 404 Permits, 401 Water Quality Certification or Isolated Wetland Permits. Additional information regarding these permits can be found in the Appendix section.

The Corps and Ohio EPA both utilize a three-tier approach to proposals to impact water resources that consist of avoidance, minimization and mitigation. Wetland setbacks can and should be a vital part of these proposals.

Design Criteria

Define the Wetland Boundary

Wetland boundaries are determined by utilizing the delineation protocols acceptable to the U.S. Army Corps of Engineers at the time. Delineations must be submitted to the U.S. Army Corps of Engineers for concurrence. Wetland setbacks should be measured in a perpendicular direction from the defined wetland boundary.

Evaluate Wetland Quality Category

Ohio EPA wetland categories are used to determine the width of the wetland setback. These are general characterizations of a wetland's quality and are determined using the most recent version of the Ohio Rapid Assessment Method as guidance (www.epa.state.oh.us/dsw/401/401.html).

Ohio EPA wetland categories are defined in the Ohio Administrative Code (OAC) 3745-1-54 (www.epa.state.oh.us/dsw/rules/01-54.pdf). They are:

Category 3 - wetlands are considered to be the highest quality;

Category 2 - wetlands are those of moderately high quality and may be good candidates for wetland enhancement;

Category 1 - wetlands are considered low quality wetlands and provide the least public health, habitat or safety services.

Maintain Hydrology

Determine the hydrologic inputs to the wetland, whether overland flow, streams, lakes, or springs. These inputs must either be maintained or substituted for other hydrologic inputs. Incorporating wetland hydrologic sources into the setback may be necessary to protect the integrity of the wetland resources.

Setback Width

The setbacks width differs with the functional capacity of the wetlands. See the Planning Considerations above for adjustments to the setback width. For most situations, Ohio EPA has concurred with the following guidelines.

- A minimum of 120 feet surrounding all Ohio EPA Category 3 wetlands, or current equivalent Ohio EPA classification,

- A minimum of 75 feet surrounding all Ohio EPA Category 2 wetlands, or current equivalent Ohio EPA classification, and
- A minimum of 25 feet surrounding all Ohio EPA Category 1 wetlands or current equivalent Ohio EPA classification.

NOTE: Category 1 wetlands often provide minimal habitat, hydrologic and recreational functions. Often times the degradation of these resources is due to the lack of setback, thus establishing setbacks from these resources may promote the restoration of these wetlands.

Vegetation

The Wetland Setback should be preserved in a natural state and established prior to any soil-disturbing activities. This area should not be mowed or disturbed in any way. If planting occurs within the setback, only native species should be utilized.

Maintenance

Wetland Setbacks should be inspected regularly to ensure that the Wetland Setbacks are being maintained in a natural state and have not been mowed, treated with herbicide (except as used to control invasive species), or developed. Wetland Setbacks and the wetlands they surround should be placed in a conservation easement to protect these resources in perpetuity. Easements should be regularly monitored and violations of easement agreements addressed in order to insure long-term protection.

References

Mack, John J. 2001. Ohio Rapid Assessment Method for Wetlands V. 5.0, User's Manual and Scoring Forms. Ohio EPA Technical Report WET/2001-1. Ohio Environmental Protection Agency, Division of Surface Water, 401/Wetland Ecology Unit, Columbus, Ohio. (www.epa.state.oh.us/dsw/401/401.html)

U.S. Army Corps of Engineers (ACOE). 1987. Corps of Engineers Wetlands Delineation Manual. Technical Report Y-87-1, Final Report, January 1987, Wetlands Research Program, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MI.

ODNR Invasive Species Information - http://www.ohiodnr.com/dnap/non_native/InvasiveSpecies.html

United States Environmental Protection Agency. 1996 Protecting Natural Wetlands: A Guide to Stormwater Best Management Practices. US Environmental Protection Agency, Office of Water, Washington, DC EPA-843-B-96-001. www.epa.gov/owow/wetlands/pdf/protecti.pdf

Castelle, A.J., C. Conolly, M. Emers, E.D. Metz, S. Meyer, M. Witter, S. Mauermann, T. Erickson, S.S. Cooke. 1992. Wetland Buffers: Use and Effectiveness. Adolfson Associates, Inc., Shorelands and Coastal Zone Management Program, Washington Department of Ecology, Olympia, WA. Publication. No. 92-10. www.ecy.wa.gov/pubs/92010.pdf

2.5 Stream Setback Area

Description

Stream setbacks (also known as streamways or riparian buffer areas) minimize property damage and protect water quality by providing areas where over bank flooding, meander migration, and stream processes freely occur and thereby encourage stability, habitat, and water quantity and quality functions. On high quality creeks and rivers these areas represent the most biologically diverse and active areas where in-stream and riparian habitat abounds, sediments are exported to floodplain areas, pollutants are assimilated and stormwater is stored and conveyed. On more impacted or lower quality creeks and rivers, stream setbacks represent areas where meander migration or floodplain redevelopment is likely to occur and where natural stream adjustments are predicted to occur.

This practice establishes the setback area based on the predicted belt width of stream, the lowest elevation ground in the valley and the stream location. The streamway is determined at intervals using the stream's drainage area and regional or locally developed stream data. Ideally, local government should map these areas so that they are centered on the areas most subject to flooding. In lieu of this mapping, individual parcels shall have stream setbacks located on site plans as this practice describes.

Note: This practice reflects the site development scale. Additional resources should be consulted when developing a model ordinance or implementing stream setbacks throughout a watershed or community.

To provide the greatest benefits, riparian areas should be predominately native vegetation, preferably forested. However, passive uses such as trails and picnic areas may be maintained.

Stream setbacks are strongly linked to the protection of public health or safety of watershed residents by setting aside areas that:

- Reduce flood hazards resulting from high flows and high velocities;
- Recharge groundwater;
- Reduce pollution in stream flows and surface water by filtering, settling and chemical transformation in floodplain areas and stream side soils;
- Reduce sediment loads from stream bank erosion; and allow recovery of previously degraded or channelized streams;
- Provide adequate room for stream meander patterns or channel migration;
- Provide high quality habitats for wildlife;
- Limit the need for costly measures such as channel armoring that would otherwise be necessary to protect structures and reduce property damage;
- Protect natural aesthetics and the environmental quality of stream corridors and the value of nearby property.

Conditions Where Practice Applies

Setbacks are appropriate for all sizes of stream channels from ephemeral or intermittent streams up to large rivers. The importance of these areas increases as a watershed is developed. Streams and associated corridors most subject to encroachment or modification (drainage areas less than 10 square miles) are most in need of established protection. These size channels are small enough that they can be more easily modified and are less likely to have adequately mapped or protected floodplain areas.

The width of the setback area is based on empirical stream data and the predicted belt width of the stream, but setback areas on sites with existing development must be implemented to minimize potential conflicts between current landuses and the stream setback. For example, setback shall be implemented to ensure that development gets no closer to the stream, thus effectively setting the setback for that parcel at the line of the existing foundation/structure. Still the recommended setback area provides the zone where channel movement is predicted and stream processes are most beneficial and should be sustained as much as possible.

Planning Considerations

The Stream Setback is Based Primarily on Stream Processes

The stream setback is based on the most critical land area needed to sustain natural stream processes. These processes are responsible for the common meandering pattern that streams exhibit and for channel and floodplain forms that are dynamically stable and beneficial to water quality and overall stream integrity. With this in mind, it should be noted that many Ohio streams are not in the condition of “best potential”. Many have been altered directly by straightening or channelization or degraded in response to landuse changes within the watershed. Thus the existing meander pattern (the stream’s plan form) is often narrower than it was historically and erosion and deposition may be working to re-establish a wider pattern along with a more dynamically stable channel form. A stream setback establishes the area in which these processes can continue to occur.

While this area provides many benefits it may need to be expanded to accomplish additional objectives. For instance, some communities may require more extensive preservation of floodplain or upland wildlife areas.

Existing Local Requirements

Some counties, townships and municipalities across Ohio have already adopted riparian setbacks. In the event that these setbacks differ from those described here, the larger of these is suggested. Please note when comparing distances that this practice predicts the full meander belt width that contains the stream, while other local stream protection setbacks may utilize a setback distance from each bank of the stream. To compare this practice to a setback distance from each bank, the latter should be doubled and added to the width of the stream for proper comparison (see Figure 2.5.1).

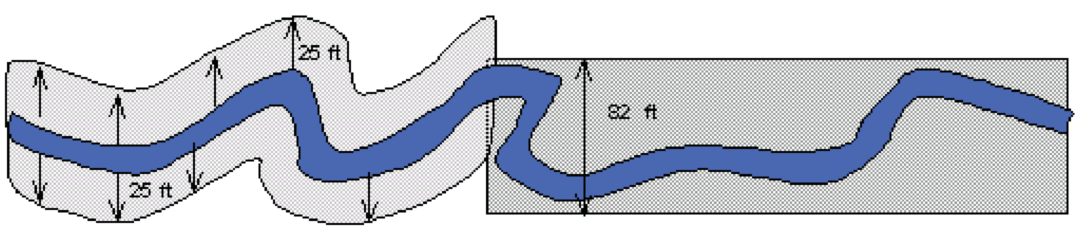


Figure 2.5.1 Comparing a traditional stream setback to the streamway-based setback.

Encourage Rehabilitation of Streams in the Stream Setback –

Because so many Ohio streams have been channelized or have degraded it is advantageous to promote channel and floodplain rehabilitation activities that provide channels with greater access to an active floodplain. This will insure more natural stability and higher function. General grading that occurs during development may provide an opportunity to rehabilitate an entrenched stream and therefore provide a higher quality stream corridor. Applicable practices may be floodplain rehabilitation, primarily lowering of high banks. This setback practice does not limit rehabilitation activities.

Adjustments to the Setback Width

In some circumstances, site conditions justify altering the width of the setback area. These may be situations of narrow, confined valleys smaller than the setback width, floodplains that extend beyond the area, wetlands contiguous to the area, or adjacent hillsides prone to slippage or being undercut as a result of stream flows. This is best accomplished with GIS or other more regional tools that can be used to incorporate adjustments to the setback area width.

For large rivers with extensive setback areas, further refinement of acceptable land uses within the area may be necessary. After maintaining a forested riparian area immediately adjacent to the river, other uses such as open fields or recreation areas are appropriate provided that the floodplain characteristics are not impaired.

Design Criteria

Calculating the Setback Area Width

The setback area width is a total width, which crosses the channel and is calculated according to the drainage area (square miles).

Size:

The setback area shall combination of two overlapping areas, one Streamway based and the other based on a minimum distance from the channel bank, equivalent to 1 channel width as illustrated in Figure 2.5.2.

The Streamway size appropriate to accommodate the meander belt is:

Streamway width = 147 (Drainage Area in square miles)$^{0.38}$

(Approximately 10 channel widths)

In addition, at no point shall the distance between the setback boundary and the channel be less than:

Minimum distance from channel = 14.7 (Drainage Area in square miles)$^{0.38}$

(Approximately 1 channel width)

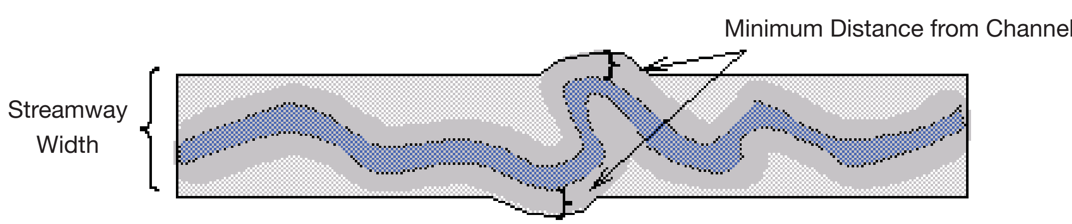


Figure 2.5.2 Setback areas combine the streamway and a minimum distance from the channel.

Location

A Streamway is more a feature of a valley than individual bends or the present location of a channel , thus the setback area may not always be exactly centered over the stream, especially as streams meander.. It is more aptly visualized as a flood path or roughly the flood way. Thus, setback areas should be fit to the valleys. They shall be positioned so that corresponding left and right boundary elevations match and the setback area incorporates the lowest elevations in the valley.

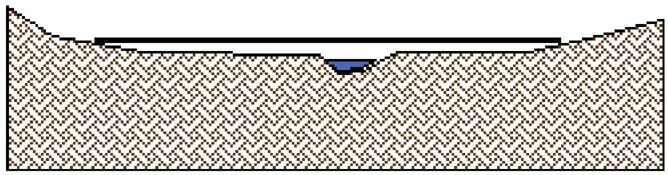


Figure 2.5.3 Center setback areas over the floodway with matching elevations at either boundary.

Avoid concentrating flow into the setback area

Maintaining diffuse sheet flow into the setback area maximizes the treatment processes that occur in riparian and floodplain areas. Convert concentrated flows from storm drains and swales (with limited drainage areas) to uniform shallow sheet flow as it enters the stream setback area. Grading and constructing level spreaders can help accomplish this. Ditches and streams with access to an active floodplain will better utilize these areas than deep entrenched channels.

Insure long-term protection of the area

Zoning, conservation easements and public ownership are options to consider long-term protection of the area. Local government may utilize zoning to set appropriate landuses for the stream setback area. In addition, many local governments will accept ownership of such properties if deeded in fee simple to the community. In this case, a credit may be applicable toward local open space or parkland set aside requirements.

Conservation easements offer one of the best ways to protect riparian areas. These maintain private ownership, while maintaining the limitations on the uses and actions that can be taken in the setback area. Easements can be held by a legally qualified conservation organization (such as a land trust) or a government agency. Easements should be regularly monitored and violations of easement agreements addressed in order to insure long-term protection.

Clearly identify the setback area boundaries on the plat map, construction plans and the site

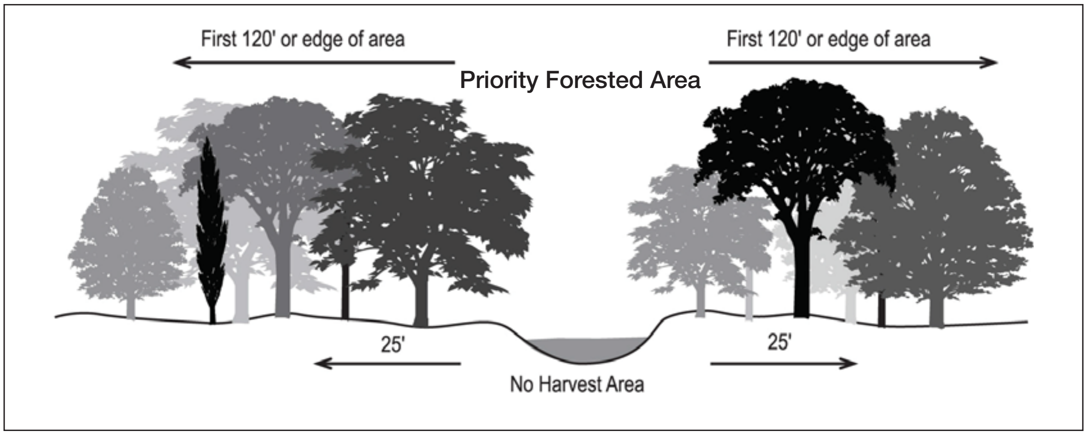
Install temporary fencing and best management practices appropriately to prevent encroachment during construction.

Following construction erect a fence or visual barrier identifying the area or portions of the area, which are to be no-mow zones or permanently forested areas. Sections of split rail or similar unobtrusive fencing provide a visual marker that will allow the area to remain distinct of other landuses.

Vegetative Goals

Setback areas are to be established in native vegetation, which for most Ohio streams is forest. Areas may also be divided into primary (closest to the stream) and secondary areas with different vegetative targets that allow for surrounding landuses. Forested areas should be maintained for a minimum of the first 50 feet of the area on either bank.

Harvesting on privately held areas should not be done within 25 feet of either bank. Removal of invasive species is allowable at anytime and is highly recommended for maintenance of the setback as a natural area.



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2.6 Water Quality Ponds

Wet extended detention pond

Description

Water quality ponds are stormwater ponds designed to treat runoff for pollutants and control increases in stream discharge and bedload transport. Water quality ponds may be predominantly dry between storm events, or have a permanent pool or even have wetland features. Water quality ponds remove pollutants by settling, chemical interaction and biological uptake by plants, algae and bacteria. The efficiency of settling suspended solids and the ability to treat dissolved pollutants is improved with the addition of wetlands and permanent pools. Water quality ponds are often designed to provide flood control by including additional detention storage above the volume specified in this practice.

Conditions Where Practice Applies

Water quality ponds are applicable to most urbanizing areas where pollutant loads are predominantly particulates and control is needed to address increased erosion potential in down stream channels.

Water quality ponds are appropriate for residential, commercial and industrial areas and are easily incorporated on sites where a stormwater pond is to be constructed to control potential flooding. Even where detention ponds are not necessary for flood control, water quality ponds can be used to address water quality and stream stability concerns.

Water quality ponds are most appropriate for larger sites, greater than 20 acres for wet or wetland ponds or greater than 10 acres for extended detention ponds. Ponds may be beneficial for smaller areas, yet have greater problems sustaining permanent pools, or issues of maintenance such as potential blocking of the outlet (due to small orifices) by trash and debris.

Existing flood control ponds may be retrofitted to meet the water quality and stream stability objectives of these stormwater ponds.

Planning Considerations

Water quality ponds may not be appropriate for ultra-urban areas where adequate space is not available or for heavy industrial areas that require extensive pollution treatment.

Water quality ponds may cause stream warming and may need additional design considerations or may not be appropriate for coldwater streams.

Ponds with dams are regulated under the Ohio Revised Code 1501: 21 Dam Safety Administrative Rules. A dam is exempt from the state's authority (ORC Section 1521.062) if it is 6 feet or less in height regardless of total storage; less than 10 feet in height with not more than 50 acre-feet of storage, or not more than 15 acre-feet of total storage regardless of height. Check with the Ohio Dept. of Natural Resources, Division of Water, for the most current requirements.

Additional upland practices may be needed to reduce nutrient loads that cause problems common to eutrophic ponds (excess algae, low oxygen levels, and odor).

For wet ponds, soils and site conditions must be appropriate to maintain a permanent pool during dry weather. Permanent pools may be difficult to maintain if the contributing watershed area is less than 20 acres and if the ratio of drainage area to water surface area is less than 6:1.

Suitable soils must be available for constructing the embankment and insuring sufficient impermeability to prevent seepage losses. A trained professional shall conduct an on-site evaluation of the proposed pond site and borrow areas prior to final design to characterize the adequacy of the site and the excavated soils for use as core trench or embankment fill. The evaluation should include a test pit at each abutment, along the centerline of the proposed embankment, the emergency spillway, the borrow area and the pool area. As a general rule, one test pit should be placed for every 10,000 square feet of area examined. All explorations shall be logged using the Unified Soil Classification System.

Treatment goals, watershed characteristics and site constraints should drive designs towards one of 3 main pond configurations:

1. *Extended Detention,*
2. *Wet Extended Detention*
3. *Wetland Extended Detention.*

Pond volume and depth characteristics depend on the type of pond being designed. In all instances, an extended detention volume (portion of the water quality volume, WQv) must be determined and treated.

Table 2.6.1 Pond types and appropriate characteristics and treatment goals

Pond Type	Minimum Drainage Area (acres) *	Drainage Area: Surface Area:	Suspended Solids Estimated Effectiveness	Dissolved Pollutants Estimated Effectiveness	Stream Warming Potential	Target Depth (apply % to surface area)
Extended Detention	≥10		Low to Moderate	Low	Moderate	3’
Extended Detention with Forebays and Micropool	≥10		Low to Moderate (improve over ED)	Low	Moderate	3’
Wet Extended Detention	≥20 or sufficient baseflow to support permanent pool	<6:1	Moderate-high	Moderate-High	High	Generally not deeper than 6-8’
Wet Extended Detention with wetland fringe	≥20 or sufficient baseflow to support permanent pool	<6:1	Moderate-high	Moderate-High	High	Generally not deeper than 6-8’ – 20% at 6-8”
Wetland	≥20 or sufficient baseflow to support permanent pool	>50:1	Moderate-high	Moderate-High	Moderate	5-20% 1.5-6’ wetland areas range from 0 – 18’ with avg of 6 – 12”
Wetland (pocket)	Dependent upon baseflow	>100:1	Variable	Variable	Moderate	5-20% 1.5 – 6’ Wetland areas range from 0 – 18” with avg of 6 –12”

*Note: Extended detention basins are appropriate for areas less than 10 acres, if the outlet is designed to prevent clogging.

Advantages of Wetland Features – Wetland vegetation, in addition to promoting settling, stabilizes deposited sediment. Wetlands can further treat stormwater in ways most other treatment practices cannot, by plant uptake, adsorption, physical filtration, microbial decomposition and shading. Wetland plants readily absorb heavy metals, and other toxic wastes.

Microorganisms that thrive in wetland plant root systems consume and decompose pollutants. These microorganisms that live among the plants are very good at breaking down poisonous organic compounds such as benzene, toluene and PCBs into harmless elements that the microorganisms and plants can digest.

Mosquito Concerns – Water quality ponds have extended detention times less than the time needed for common vector mosquitoes to hatch (generally 72 hours). But it is still important to design and maintain stormwater ponds in order to prevent conditions most favorable to mosquitoes. When designing and maintaining stormwater ponds apply the following considerations:

- Avoid stagnant water by assuring there is sufficient flow to support a wet or wetland ponds.
- Maintain the outlets so that detention does not occur beyond the extended detention period.
- Design wet ponds with wetland benches and wetlands with varying depths (mix of deeper water and wetland areas) in order to have improved habitats for natural mosquito predators like small fish, birds, dragonflies and aquatic insects.
- For areas that will have standing water without wave action or deeper water, consider aeration to prevent stagnation.

Design Criteria (Applicable to Each Pond Type)

Water Quality Volume (Applicable to all pond configurations)

The water quality volume (WQv) is the volume of runoff that is treated in a water quality pond. Depending upon the type of pond (dry extended detention, wet or wetland) all or a portion of this volume is stored above wetland or permanent pool features and drained over a 24-48 hour period. Detaining this volume has two stream protection objectives: reducing the pollutants suspended in the runoff and reducing the energy of common storm events responsible for most channel erosion. The water quality volume is calculated using equation 1 below, adapted from Urban Runoff Quality Management (ASCE/WEF, 1998). This is required by the Ohio EPA NPDES general permit for construction activities.

$$WQv\ (ac\text{-}ft) = C * 0.75 * A / 12 \qquad \text{(Equation 1)}$$

Where:

C = runoff coefficient

A = area draining into the BMP in acres

The runoff coefficient, C, is calculated using the following equation or alternatively values provided in the current Ohio EPA NPDES general permit for construction activities.

$$C = 0.858i^3 - 0.78i^2 + 0.774i + 0.04 \qquad \text{(Equation 2)}$$

Where:

i = watershed imperviousness ratio, the percent imperviousness divided by 100

Note: The Ohio EPA NPDES stormwater general permit for construction activities requires that the water quality volume be increased by 20% for capacity lost over time due to sediment accumulation.

Pond Configuration

Configure the pond so that water quality treatment is optimized through pond shape and flow length. Improved settling of pollutants occurs as the flow length is maximized. Optimally, designs will avoid the problems of dead storage or incoming water short-circuiting through the pond and the resuspension of deposited sediments.

Forebays and micropools, pool water at the inlets and outlet of a pond in order to improve the effectiveness and ease of maintenance of water quality ponds. The shape and grade of pond side slopes also strongly influence pond effectiveness and potential safety.

1. Length to Width Ratio

Wedge shaped or ponds that are longer than wide will prevent flow from short-circuiting the main body of water. The ratio of flow length to pond width should be at least 3:1. To increase a pond's flow length, the contours of the pond may be configured to form baffles or an extended flow path. Constructing submerged aquatic benches to form cells will enhance flow routing (Figure 2.6.1).

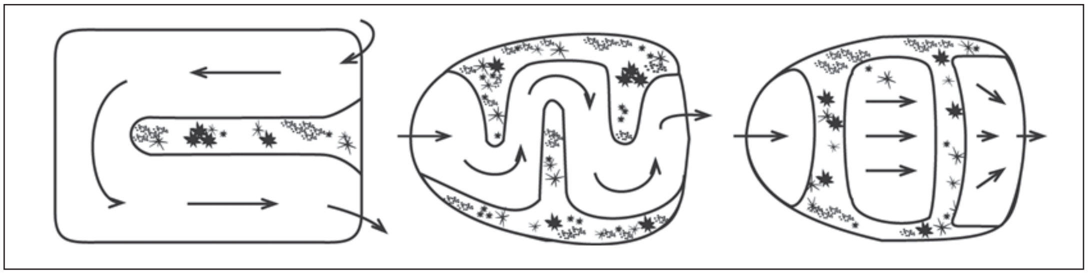

Figure 2.6.1 **Flow Routing to Enhance Water Quality Treatment**

2. Side Slopes

Varying the slope to create benches above and below waterlines increases safety and stability and can create water quality features such as wetland benches in permanent pools. Slopes should not be steeper than 3:1 or shallower than 12:1.

3. Forebay(s)

A forebay is a settling pool located at the inlet to a pond. It is separated from the rest of the pond by a level dike often planted with emergent wetland vegetation. Forebays are primarily used to improve the settling efficiency of a pond but they also reduce maintenance by promoting settling in a confined, easily accessible location.

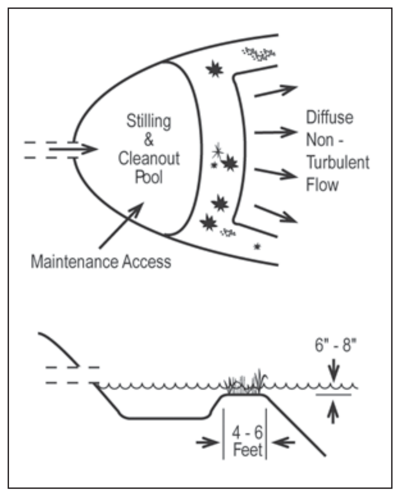

Figure 2.6.2 **Forebay**

Forebays promote settling by: segmenting or dividing the pond into cells which reduce mixing and promote plug flow; by converting the high velocity concentrated inflow from a pipe to a wide uniform slow flow to the normal pool area; and by dissipating flows through emergent vegetation. See Figure 2.6.2.

Forebay Size – forebay for a single inlet should occupy from 8-25% of the normal pool area. Forebays should be large enough to avoid scour and resuspension of trapped sediment and sized for ease of construction and cleanout. Forebays should have a water depth of at least 3 ft.

Forebay Outlet – Provide an outlet to the main pond, consisting of a level spreader or submerged level dike. A submerged dike separating the forebay from the rest of a wet pool or wetland should be 6-12 in. below the normal water surface elevation and provide a non-erosive overflow. It should also be planted with hardy emergent wetland vegetation. See the wetland extended detention pond section below for more information on planting.

Forebay Maintenance Access – To accommodate relatively frequent sediment cleanout, easy equipment access should be provided to the forebay. This should include gradual slopes without obstructions and an access easement. Additionally a drain should be installed under the dike so that the forebay can be drained during maintenance operations.

4. Micropool

For wetland and predominantly dry extended detention stormwater ponds, a micropool is recommended in front of the outlet. The micropool allows a reverse slope pipe or other non-clogging outlet to be used. The micropool should be 4-6 feet deep and equal to 10% of the volume of the water quality volume.

5. Non-clogging Outlet

Extended detention outlets often require small orifices or controls and must be designed to be non-clogging. A reverse flow pipe is one way to configure an outlet to better trap floating pollutants and to be less clogging (see figure 2.6.3). Reverse flow pipes draw water from below the water surface to trap floating debris that would otherwise clog the outlet.

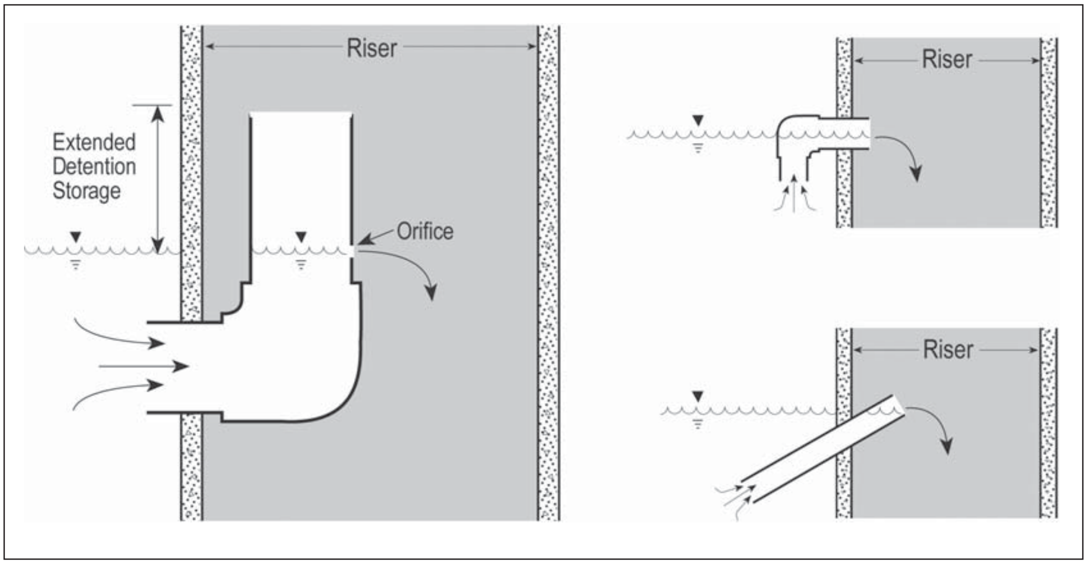

Figure 2.6.3 **Reverse Flow Structures Reduce Clogging and Trap Floating Pollutants**

A reverse flow pipe is designed to draw water below the pond's surface and above the midpoint of the normal permanent pool elevation. They may be constructed with a pipe on a negative slope or with a turned pipe elbow. Reverse flow outlets may be constructed with a straight pipe set on a negative slope. A pipe with a 90-degree elbow also may be used either inside the riser and facing upward or outside the riser facing down (see figure 2.6.3).

6. Pond Drain

It is recommended that a drain be installed such that the entire pond can be drained for maintenance or repair purposes.

7. Additional Specifications for Pond Construction

Embankment ponds must be well constructed and built according to NRCS Conservation Practice Standards 378 (Pond) addressing issues such as:

- Ponds must incorporate emergency spillways designed to safely convey flows exceeding design storm flows.
- Outlet structures should be built to withstand floatation and incorporate anti-vortex and debris or trash rack devices.
- Embankments and principal spillway shall utilize adequate soils and compaction, core trenches and anti-seep collars.

Dry Extended Detention Basin – Design Criteria

Detention Volumes

The extended detention volume is equal to the water quality volume (WQv) found in equation 1. An additional capacity of 20% must be provided within the water quality volume for sediment accumulation. This additional volume may be utilized in forebays at inlets and in a micropool at the outlet, which will improve the maintenance and efficiency of the pond.

Local government may require additional detention volumes for peak discharge control (flood control). Appropriate design procedures, including routing design storms through the basin, shall be used to insure the pond and outlet geometry meet local and state requirements. See the figure below.

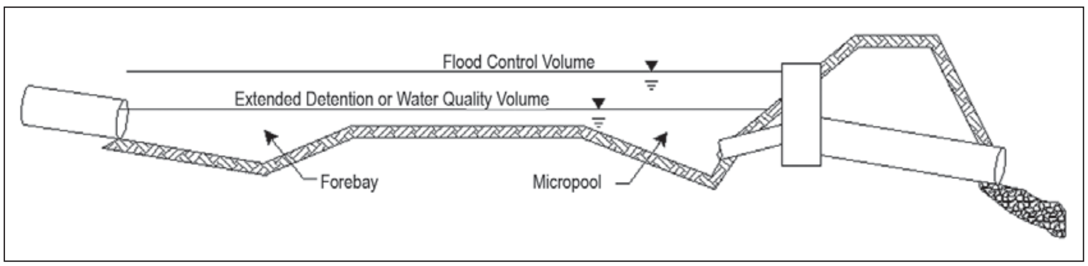

Fig 2.6.4 **Storm Water Pond with Extended Detention and Flood Control Volumes**

Outlet Design

Design the outlet structure (principal spillway) to draw down the extended detention volume over a 48-hour period. The outlet should empty less than 50% of this volume in the first 16 hours.

Peak discharge control (flood control) required by local government can be incorporated into the spillway with additional control devices (e.g. orifices or weirs) above the extended detention outlet. This type of multiple outlet spillway incorporates outlet controls for each attenuation goal.

Permanent Pool

Dry extended detention basins do not have a permanent pool except for the establishment of forebays at inlets and a micropool at the outlet. While these are not required, they increase the effectiveness of the pond and the ease of maintenance. More information is provided on these in the design criteria applicable to all ponds above.

Wet Extended Detention Basin – Design Criteria

Detention Volumes

Wet extended detention ponds detain a volume equal to 75% of the WQv found with equation 1 (0.75 WQv) above a permanent pool. See figure 2.6.5.

Local government may require additional detention volumes for peak discharge control (flood control). Appropriate design procedures, including routing design storms through the basin, shall be used to insure the pond and outlet geometry meet local and state requirements. See the figure below.

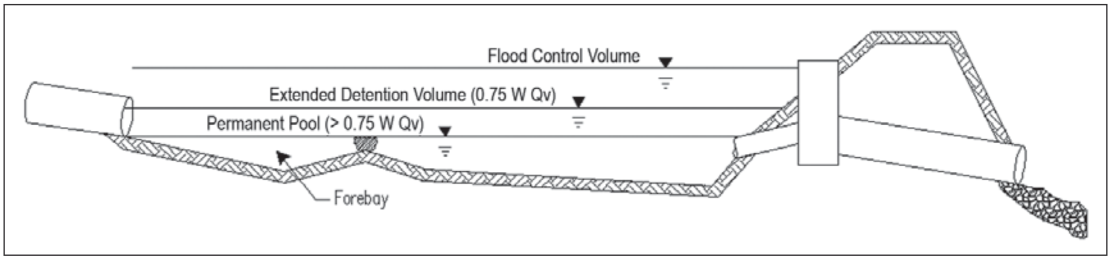

Figure 2.6.5 **Wet Storm Water Pond with Extended Detention and Flood Control Volumes**

Outlet Design

Design the outlet structure (principal spillway) to draw down the extended detention volume over a 24-hour period. The outlet should empty less than 50% of this volume in the first 8 hours.

Peak discharge control (flood control) required by local government can be incorporated into the spillway with additional control devices (e.g. orifices or weirs) above the extended detention outlet. This type of multiple outlet spillway incorporates outlet controls for each attenuation goal.

Permanent Pool Volume

The permanent pool of a wet extended detention pond is equal to three fourths of the WQv (0.75 WQv) found with equation 1 plus an additional volume equal to 20% of the WQv (0.2 WQv) added for sediment accumulation. Thus the original capacity of the permanent pool shall be equal to 0.95 of the water quality volume. This volume may include forebays, cells created within the permanent pool for increasing efficiency.

Permanent Pool Depth

The mean depth of the permanent pool should be between 3 and 6 feet in order to optimize settling of suspended particles. This is calculated by dividing the permanent pool's storage volume by the pool's surface area. A pool that varies in depth will allow diverse conditions for wetland vegetation and portions, which are deep enough for fish. If fish are to be maintained in the pool, approximately 25% of the pool should be at least 6 to 8 feet deep.

Overly shallow pools will have increased problems with algae and the re-suspension of deposited sediments by wind or as runoff enters the pond. Overly deep pools may encourage thermal stratification and anaerobic conditions at the bottom, which allow pollutants (e.g. metals and phosphorus) to be released from sediments. Deep pools are often associated with short flow paths from inlet to outlet, allowing runoff to short-circuit treatment provided by flow through the main volume of the pool.

Wetland Benches

Wet extended detention ponds may include wetland environments that greatly enhance water quality treatment by establishing a shallow aquatic bench around the main pool. These areas also improve safety by creating a vegetative barrier to discourage children from venturing into deeper water and reducing the hazard of steep grades at the pond edge.

When used as one water quality design feature within a wet extended detention pond pond, wetland vegetation should occupy at least 20% of the wet pool's water surface. It is also recommended that benches be at least 6 feet wide and have depths of 6 to 12 inches on average and not exceed 18 inches. See the Design criteria for wetland extended detention ponds for guidance on establishing wetland plants.

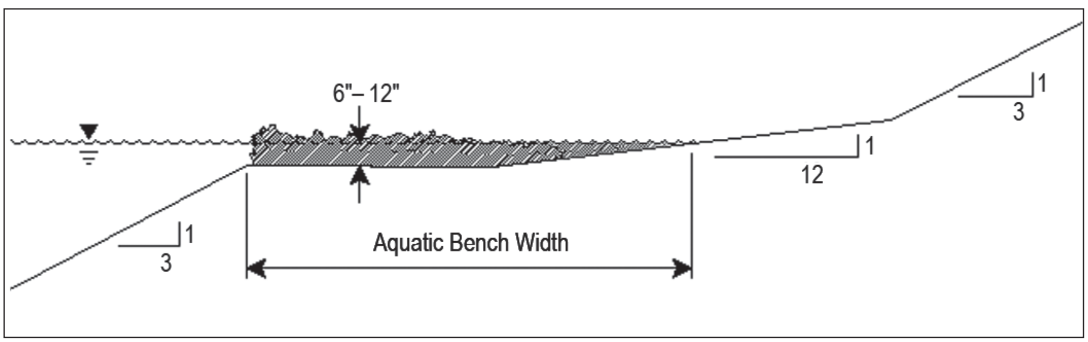

Figure 2.6.6 **Grading of Side Slope to form a Wetland Bench**

Reducing Thermal Impacts Through Shading

Warm water released from a permanent pool may adversely impact the thermal regime of receiving streams, particularly if the receiving water is a cold-water fishery. The pool acts as a heat sink between storm events during the summer months. Water released downstream from the pond can be as much as 10 F warmer than naturally occurring base flow. Large impervious surfaces also warm surface runoff significantly which can be critical to stream systems where fish and other aquatic life are threatened by high summertime water temperatures.

Add Shading – Shading a pond can significantly reduce thermal impacts. Trees planted around the pond, particularly on the south and west sides offer the most protection from the summer sun. Trees planted on islands or peninsulas should also be considered. Because tree roots can damage dams, trees must not be planted on the embankment itself. Wetland vegetation also contributes to shading and reduces thermal impacts.

Leaf litter introduces nutrients to the pond and adds to the accumulation of sediment. While nutrients and sediment are pollutants, nutrients in plant material or detritus are more readily utilized by aquatic insects and incorporated into the food chain. Fallen leaves are a vital part of aquatic environments, whereas soluble nutrients and nutrients attached to fine sediments easily wash through a pond system or promote algal growth.

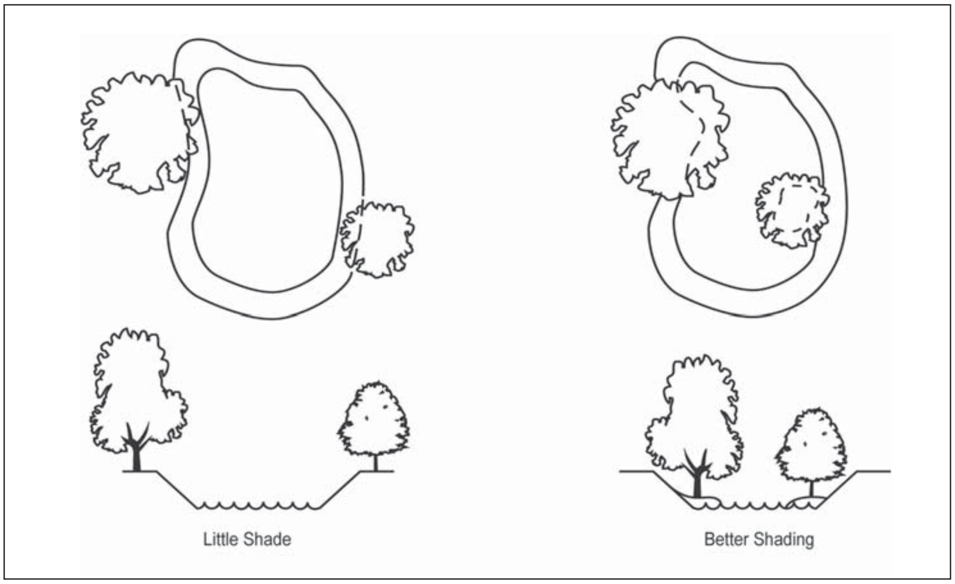

Figure 2.6.7 Tree Placement to Shade Ponds and Reduce Thermal Impacts

Wetland Extended Detention Basin – Design Criteria

Detention Volumes

Wetland extended detention ponds detain a volume equal to the water quality volume (1.0 WQv) found in equation 1 above the permanent wetland pool.

Local government may require additional detention volumes for peak discharge control (flood control). Appropriate design procedures, including routing design storms through the basin, shall be used to insure the pond and outlet geometry meet local and state requirements. See the figure below.

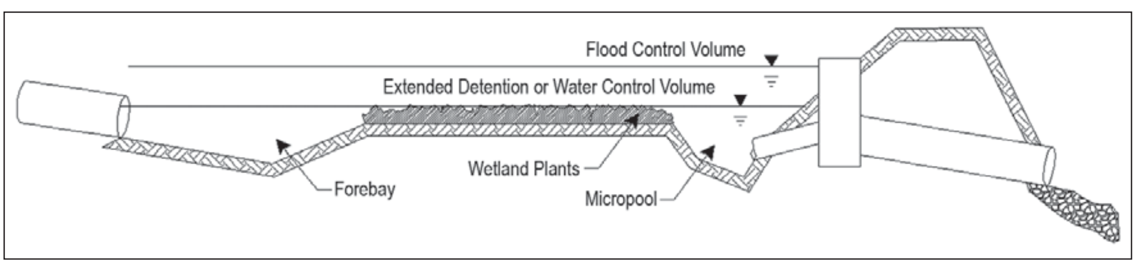

Figure 2.6.8 Wetland Storm Water Pond with Extended Detention and Flood Control Volumes

Outlet Design

Design the outlet structure (principal spillway) to draw down the extended detention volume over a 24-hour period. The outlet should empty less than 50% of this volume in the first 8 hours.

Peak discharge control (flood control) required by local government can be incorporated into the spillway with additional control devices (e.g. orifices or weirs) above the extended detention outlet. This type of multiple outlet spillway incorporates outlet controls for each attenuation goal.

Permanent Wetland Pool Volume

The permanent pool volume is based on the designer's assessment of sufficient runoff and base flow to sustain a wetland pool. The designer should assess the change in storage volume over time based on water entering and leaving the wetland. This water budget should include water entering from precipitation, runoff, base flow, groundwater and any water to be pumped. Water leaving should include evaporation, expected plant transpiration, stormwater outflow, and seepage or percolation. Greater guidance on wetland creation and water budgets can be found in the Natural Resource Conservation Service Engineer Field Manual Chapter 13.

Add a volume equal to 20% of the water quality volume to the permanent wetland pool volume for accumulation of sediment overtime. This total volume should include forebays, cells and micropools graded within the permanent pool for increasing efficiency.

Wetland Depth

Wetland pool depths should generally range between 6-18 inches. The average depth should be between 6 and 12 inches. This depth may vary but must accommodate 1) the depth appropriate for the type of wetland vegetation planted, and 2) adequate volume of runoff stored within the wetland. Wetland diversity and stability will be improved if a variety of depths are created with complex subsurface contours and irregular shapes to provide more edge effect.

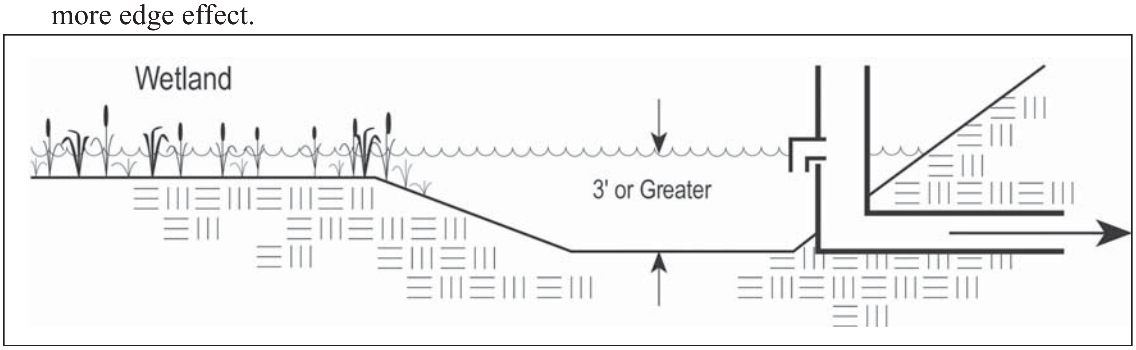

Figure 2.6.9 Micropool: Open Water Around Outlet Structure of Wetland

A micropool, that is a deep area, greater than 3 feet, should be created at the outlet structure so that vegetation and sediment buildup do not interfere with outflow from the basin. Incorporating a deep pool at the inlet to the pond may be used to promote initial settling and dissipate concentrated inflow.

Establishing Wetland Vegetation

Six to eight species of wetland plants should be planted. Species that have worked well in constructed urban wetlands include: common three square, arrowhead, soft stem bulrush, wild rice, pickerelweed, sweetflag, smartweeds, spike rush, soft rush, and a number of other sedges.

Vegetation may be established one or a combination of the following methods: planting nursery stock (plants or rhizomes), mulching with soils from an existing wetland or allowing volunteer establishment. Using only volunteer establishment is discouraged since it often leads to mono-typical stands of invasive or undesirable species.

Planting Layout – Initial planting should cover at least 30% of the wetland area, concentrated in several portions of the pond and have densities of four to five plants/square yard. Planting clusters of single species will improve the quality and diversity plantings. Plants should be planned for their appropriate depth within the permanent wetland pool.

Grading or Disking the Basin – The basin substrate should be soft enough to permit relatively easy insertion of the plants into the soil. If the basin has been recently graded or excavated, the soil should be sufficiently soft. However, if the basin soil is compacted or hard subsoil is encountered, planting will be difficult. In these cases, it is recommended that the basin soil be disked or otherwise loosened before planting.

Flood and Drain Prior to Planting – If nursery stock will be used, it is recommended that the wetland area be flooded for a period of time (6-9 monthes, USEPA) prior to draining and planting.

Treatment of Plant Material – For successful establishment of wetland vegetation the nursery stock must be correctly handled prior to planting. For growing plants, this consists of keeping the roots moist at all times, and in keeping the plants out of direct sunlight as much as possible. Vegetation should be planted as soon as possible to avoid damage during on-site storage. Dormant plant material should be stored under conditions similar to those under which the material was stored at the nursery.

When planting container plants dig holes about one third bigger to allow root systems an un-compacted area in which to develop.

Mulching with Wetland Soils – If an area is mulched with soil from an existing wetland, plants should be allowed to germinate and grow for a period prior to fully inundating the wetland pool. Care should be taken not to allow the newly germinated plants to dry out.

Transition from temporary sediment control basin to permanent stormwater quality pond.

Often permanent stormwater management ponds are used for sediment control during construction. In most cases, these facilities will need dewatering and sediment removal in order to insure that the pond has the appropriate volume for permanent stormwater design. This includes removal of temporary risers used for sediment control and reseeding bare soil or establishing wetland vegetation in designated areas within the pond.

Maintenance of Water Quality Ponds

While maintenance is inevitable, the amount of maintenance required and its cost can vary considerably depending on the initial design of a pond. A number of design features are helpful in this regard:

Sediment Storage – Reduce the frequency of sediment cleanout easily by increasing the volume available for sediment storage. Increasing the permanent pool volume by 20% or according to the predicted sediment loads is recommended. Ponds used for sediment control during construction should be cleaned out when the site is stabilized, as the cost of cleanout will be considerably less expensive during construction than in the future.

On-Site Disposal – Transporting dredged sediment is often the largest cost associated with pond cleanout. This can be avoided by providing an area on-site for future sediment disposal. A disposal site should be designated during site design.

Forebay – Trapping most sediment in a confined, easily accessible forebay can reduce maintenance costs.

Maintenance Easements – Maintenance easements must be established to allow access to the pond, particularly to the forebays, embankment, outlet structure and sediment disposal areas.

Disposal of Pollutants – Water quality treatment practices are intended to trap pollutants. The fate of these pollutants must be considered. Trapped sediment is usually clean enough for on-site use. The large volume of sediment poses the most common disposal problem. Sediments may also have high concentrations of hydrocarbons, nutrients and heavy metals. Soil tests should be done if the pond has received spills, is in a highly industrial area, or if the watershed has intensive traffic.

Sediment should be spoiled in areas, which will keep pollutants bound in the sediment (e.g., metals and phosphorous). To avoid these pollutants from becoming soluble, acid and anaerobic conditions, such as wetlands, should be avoided.

Table 2.6.3 Typical Maintenance Activities For Water Quality Ponds (USEPA) Adapted from WMI, 1997 and SMRC

Schedule	Activity
Monthly	Mow embankment and clean trash and debris from outlet structure. Address any accumulation of hydrocarbons.
Annually	Inspect embankment and outlet structure for damage and proper flow. Remove woody vegetation and fix any eroding areas. Monitor sediment accumulations in forebay and main pool.
Semi-Annually	Inspect wetland areas for invasive plants.
3-7 years	Remove Sediment from forebays.
15-20 years	Monitor sediment accumulations in the main pool and clean as pond becomes eutrophic or pool volume is reduced significantly.

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2.7 Infiltration Trench

Description

An infiltration trench is a rock-filled trench that receives stormwater runoff, allowing it to infiltrate into the ground. These structures provide temporary underground storage in the form of a trench or other storage chamber filled with uniform graded stone. Infiltration trenches are used in conjunction with sediment removal practice so that most suspended solids are removed before passing runoff into the infiltration trench. This is typically accomplished by passing runoff through a forebay (see water quality ponds), a grass filter strip or a water quality swale prior to the trench.

Infiltration is the single most efficient post-construction stormwater practice, providing several benefits other control practices don't. Most notably, infiltration tends to reverse the hydrologic consequences of urban development by reducing peak discharge and increasing base flow to local streams. Unfortunately, infiltration trenches must be very carefully constructed to ensure they will continue to function, and they often have high long-term maintenance requirements. Infiltration practices also are limited by site constraints, particularly soils, which must be within a narrow range of permeability.

Conditions Where Practice Applies

Smaller Sites – Infiltration trenches are generally not considered practical for sites larger than 5 acres. Used in small areas they offer flexibility in incorporating water quality treatment into a site's drainage system. They may be used prior to runoff entering the site's drainage system, such as along parking lot perimeters. They can be located in small areas, which cannot readily accommodate wet ponds or similar facilities.

Soil Hydraulic Conductivity – Hydraulic conductivity describes the ability of water to move through a soil. Hydraulic conductivity should be at least 0.52 inches per hour but not more than 2.4 inches per hour for infiltration trenches. These rates represent average or saturated soil conditions, not dry conditions. Rates slower than the minimum will lead to trench sizes that are unreasonably large and are more prone to failure. Higher infiltration rates will not provide adequate runoff treatment or protection against ground water contamination. Higher hydraulic conductivity will not provide adequate runoff treatment and protection against groundwater contamination. Trenches should not be constructed on undisturbed soils that have been filled. On-site evaluation of soil parameters related to hydraulic conductivity and groundwater by a trained professional is recommended..

Industrial or Other Areas of Potential Ground Water Contamination – This practice should not be used in heavy industrial developments, areas with chemical storage, pesticide storage or fueling stations.

Stable Slope – Trenches should not be used in slip prone areas where they may cause slope instability.

Hydrologic Recharge – Infiltration practices help reduce runoff and may help support recharge of groundwater and baseflow to streams. This practice may be a particularly desirable option when the receiving stream is a cold water habitat.

Planning Considerations

Sediment Clogging – The principle threat to infiltration trenches and a common reason for their failure is sediment clogging and sealing off of the permeable soil layer. An effective sediment trapping system is an essential part of all infiltration trench designs. Vegetated swales, buffer strips or sediment settling ponds should be planned so that most sediment is removed from runoff prior to reaching the infiltration trench. Additionally infiltration trenches may not be installed until disturbance from construction has ended and soils are stabilized.

Groundwater Protection – Precautions must be taken to guard against the facility introducing contaminants into water supply aquifers. Excessively permeable soils will not effectively stop pollutants and should not be used for infiltration practices Infiltration trenches should be used with caution in well-head protection areas, i.e., areas of the state where the public water supply comes from ground water. At a minimum, infiltration structures should not be located within 100 feet of an active water supply well. A minimum vertical separation of 3 feet between the bottom of the infiltration trench and the seasonal high water elevation of the ground water must be maintained, although larger separations are recommended where achievable. Normally, infiltration through soil is a highly effective and safe means of removing pollutants and protecting groundwater from contamination. Removal mechanisms involve sorption, precipitation, trapping, and bacterial degradation or transformation and are quite complex.

Considerations for Cold Climates – The design volume of the infiltration trench may need to be increased in order to treat snowmelt. In addition, if the practice is used to treat roadside runoff, it may be desirable to divert flow around the trench in winter to prevent infiltration of chlorides from road salt. Finally, a minimum setback of 20 feet from road subgrade is required to ensure that the practice does not cause frost heaving.

Design Criteria

Diversion – Storm water runoff should be directed to the infiltration trench via dispersed sheet flow wherever possible. A grass filter strip of at least 25 feet must precede the infiltration trench in these situations. Where runoff is directed to the infiltration trench as concentrated flow (via a swale, storm sewer or other discrete conveyance), the infiltration trench must be designed "off-line" such that flows in excess of the Water Quality Volume (WQv) are diverted around the infiltration trench.

In addition, a diversion that allows the trench to be bypassed when the pretreatment system becomes clogged or otherwise fails should be included in the design. This can be accomplished by providing a drain valve.

Soil Hydraulic Conductivity – Soil infiltration rates within the trench must be between 0.52 and 2.4 inches per hour. The soil should have no greater than 20 percent clay content and less than 40 percent silt/clay content.

The list of soils in Ohio that meet the required infiltration rates and are potentially suitable for the installation of infiltration trenches can be found in Appendix E. However, do not use this or county soil surveys to determine final suitability. Site-specific soil tests should be performed to confirm that the hydraulic conductivity falls within the required range. A certified Soil Scientist or other trained professional shall perform one test hole per 5000 feet, with a minimum of two borings within the planned facility location. This evaluation shall include an evaluation of the normal and seasonal high groundwater levels.

Pretreatment – The potential for failure of infiltration practices due to clogging by sediments is high. Failure will result if sediment is not trapped before runoff enters the trench. Thus, it is imperative that the facility design includes a durable, maintainable pretreatment system for removing sediment from stormwater before the trench. This can be accomplished by installing a plunge pool. Where infiltration trenches are used to treat rooftop runoff with drainage areas of 1 acre or less, pretreatment can be accomplished by providing an underground trap with a permanent pool between the downspout and the infiltration trench (Fig 2.7.1). The trap must be accessible, but sealed tightly so that it does not become a breeding ground for mosquitoes.

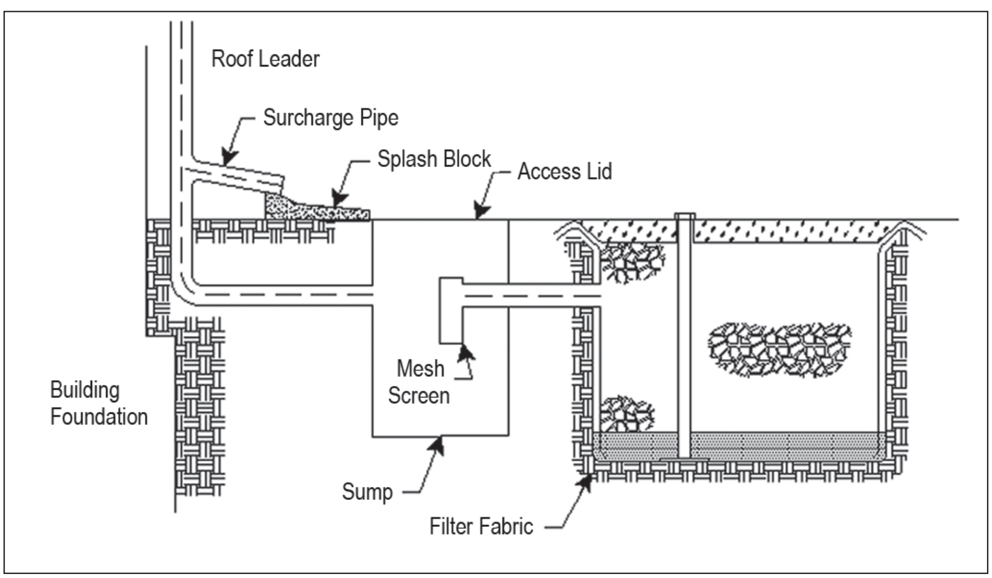


Figure 2.7.1 **Underground pretreatment facility and infiltration trench for treating rooftop runoff.**

Sizing the Pretreatment Facility – The size of the pretreatment facility is based on the infiltration rate of the soil in which the infiltration trench is built. For soils with infiltration rates of 2.0 inches per hour or less, the pretreatment facility shall be sized to contain 25% of the WQv. For infiltration rates greater than 2.0 inches per hour, the pretreatment facility shall be sized to contain 50% of the WQv.

Exit Velocity from Pretreatment Facility – The velocity of runoff as it exits from the pretreatment device must be non-erosive.

Drain Time Requirements – The practice is to be designed to infiltrate the Water Quality Volume (WQv, see page 30 of this chapt.) through the bottom floor of the structure in 24 to 48 hours. Drain times in excess of 72 hours should be avoided to prevent mosquito-breeding habitat from forming. Flows in excess of the WQv are to be diverted around the trench.

Dimensions – The dimensions of the storage reservoir (infiltration trench) are made by fitting the length, width and depth into a configuration, which satisfies drain time and storage volume requirements. The trench dimensions shall be sized by accepted engineering methods such as those outlined below:

1. Determine Initial Storage Depth – The bottom of the infiltration trench must be deeper than 2 feet to avoid freezing and shallow enough to leave at least 3 feet between the seasonal high-water table or bedrock and the trench bottom. Soil morphology also must be considered in determining the dimensions of the storage reservoir to utilize the optimum horizons or strata. The presence of a thin, slowly permeable soil horizon may require a trench depth which completely penetrates it to more permeable underlying material. Long trenches may need to be curved parallel to the topographic contour in order to keep the trench bottom elevation within the optimum depth in the soil profile.

2. Determine Area of Trench Bottom – The bottom of the trench is to be completely flat so as to allow runoff to infiltrate through the entire surface.

$$A_{\min} = \frac{WQ_v}{Porosity * (E * T)}$$

Where: A_{min} = Minimum area of the bottom of the trench (ft^2);

WQ_v = Water Quality Volume (ft^3); (Trench volume less stone volume).

E = Exfiltration Rate (ft/hr); (Soil infiltration rate at trench bottom)

T = Drain Time (hr) (Must be 24 to 48 hrs per Ohio EPA requirements)

The excavated volume of the trench is the WQ_v divided by porosity or the void space of the stone.

Determine Length and Width – A long, narrow trench is less affected by water table mounding. If depth to seasonal high-water table or bedrock is within 5 feet of the trench bottom, it is advisable to design the trench as long and narrow as possible. Otherwise, the configuration of the trench is not restricted and is only limited by site design constraints.

Stone – The infiltration trench is filled with clean, washed aggregate. Stone with a diameter of between 1 and 3 inches should be used.

Geotextile – The sides and top of the trench must be lined with a non-woven geotextile to restrict the amount of sediment entering the structure. The top layer of the geotextile should be covered by 6-to-12 inches of smaller sized gravel (0.75-inch diameter). This top layer of gravel and geotextile must be replaceable. The bottom of the trench must NOT be covered with geotextile to prevent clogging with sediment. The geotextile should meet the following specifications:

Table 2.7.1 Geotextile specification

Specification	Criteria
Material	ASTM D-3776
Weight, oz/yd2	4
Grab tensile strength, lb/min (ASTM D4632)	90
Elongation at break, % (ASTM D4632)	30
Toughness, lb/min	6000

Bottom Sand Filter – To promote continued infiltration, the bottom of the trench should be covered with a clean layer of sand, approximately 6 inches deep.

Observation Well – An observation well, consisting of a perforated vertical 6-inch diameter PVC pipe with lockable cap should be installed in the trench to monitor performance. The original depth of the well must be marked on the top of the well.

Overflow – Infiltration trenches, like all stormwater facilities, must be designed to handle storms, which exceed their storage capacity without damage. Discharges must be non-erosive and overflow must always pass around the infiltration trench without being restricted by sediment filters. For example, the infiltration trenches that accept concentrated runoff from a subsurface pipe must have an overflow structure that collects overflow from within the structure rather than forcing runoff up and out through the geotextile cover.

Construction Sediment – Due to their sensitivity to sediment, infiltration trenches should not receive runoff from disturbed areas of the site. It is advisable to construct the infiltration trench only after the contributing drainage area has been stabilized.

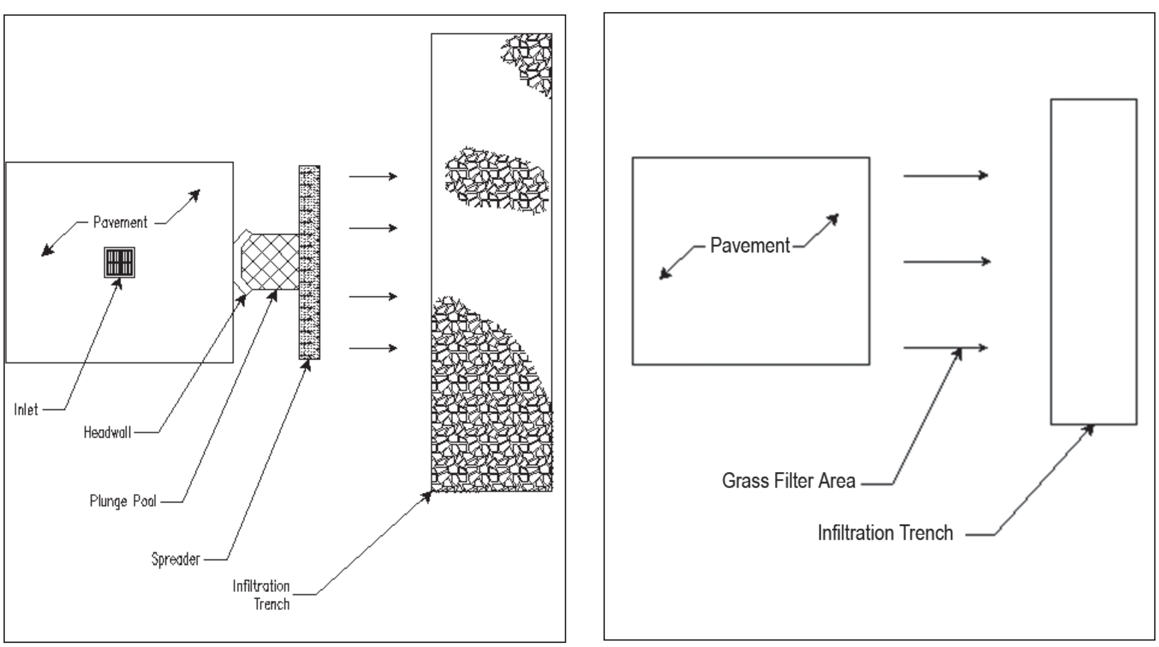


Figure 2.7.2 Typical Infiltration Trench with Plunge Pool

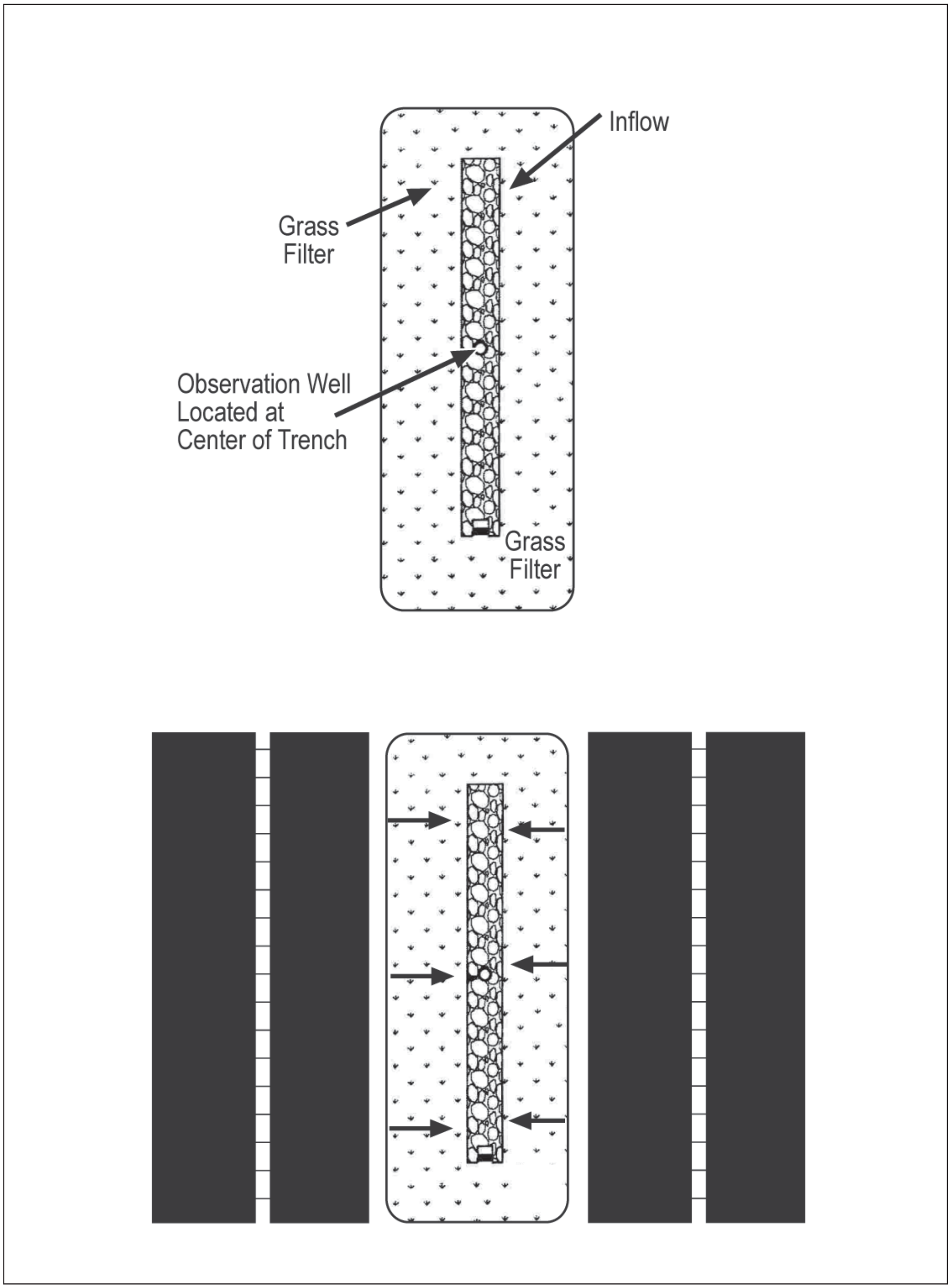


Figure 2.7.3 Illustration of a median strip trench design

Infiltration trenches have a high rate of failure. In one study in Prince George's County, Maryland (Galli, 1992), less than half of the trenches investigated were still functioning properly and less than one third still functioned properly after 5 years. However, many of these structures did not incorporate pretreatment of runoff. Thus, it is critical to ensure that proper pretreatment of runoff has been provided.

Maintenance

The following regular maintenance and inspection protocol is recommended:

Table 2.7.2 Typical Maintenance for Infiltration Practice

Schedule	Activity
Twice per year	Check observation wells following 3 days of dry weather. Failure to percolate within this timeCheck observation wells following 3 days of dry weather. Failure to percolate within this time period indicates clogging. Inspect pretreatment devices and diversion structures for sediment build-up and structural damage.
Standard maintenance	Remove sediment and oil/grease from pretreatment devices as well as overflow structure.
Upon failure	Total rehabilitation of the trench should be conducted to maintain storage capacity within 67% of the design treatment volume and 72-hour exfiltration rate limit. Trench walls should be excavated to expose clean soil.
Annually	Trim adjacent trees to assure that drip-line does not extend over the surface of the infiltration trench.

Adapted from WMI, 1997 and SMRC

References

ASCE/WEF (American Society of Civil Engineers/Water Environment Federation), 1998. Urban Runoff Quality Management, WEF Manual of Practice No. 23, ASCE Manual and Report on Engineering Practice No. 87, Alexandria and Reston, VA.

Guidance Manual for On-Site Stormwater Quality Control Measures, Sacramento Stormwater Management Program, City of Sacramento, CA, Dept. of Utilities and County of Sacramento, Water Resources Division, January 2000. Available on-line at http://sacstormwater.org/const/manuals/dl-on_site.html.

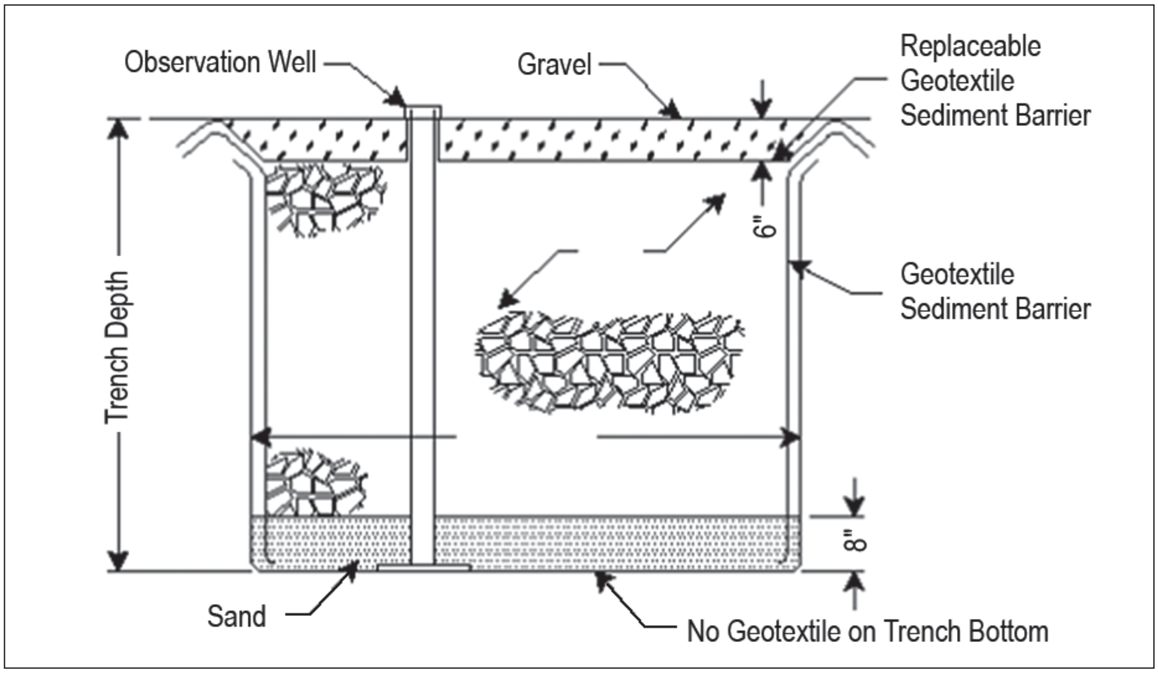
National Menu of Best Management Practices for Storm Water Phase II, USEPA, August 15, 2002. Available on-line at http://cfpub.epa.gov/npdes/stormwater/menuofbmps/menu.cfm.

New York State Stormwater Management Design Manual, Center for Watershed Protection for the New York State Department of Environmental Conservation, October 2001. Available on-line at http://www.dec.state.ny.us/website/dow/swmanual.html.

Operation, Maintenance and Management of Stormwater Management Systems, Watershed Management Institute (WMI) for U.S. EPA Office of Water, 1997. Washington D.C.

Specifications
for

Infiltration Trench



1. SEDIMENT SHALL BE PREVENTED FROM ENTERING THE INFILTRATION TRENCH. Sediment clogging and sealing off the permeable soil is the most common cause of infiltration trench failure. Runoff from the construction site shall NOT be allowed to flow to the trench until construction is complete and upslope areas have been stabilized. If storm drains enter the infiltration trench directly and cannot be rerouted, they shall be sealed with a masonry plug until all contributing drainage areas are stabilized.
2. The infiltration trench design shall include a system for removing sediment from stormwater before it enters the infiltration structure. However, this system shall NOT be used to control sediment during construction.
3. Trench excavation and backfilling of sand and rock shall be done when the soil moisture is low enough to allow the soil to crack or fracture. No trench excavation or fill shall occur on wet soil to prevent compaction and maintain soil permeability.
4. Bottom Sand Filter - The bottom of the trench shall be covered with an 8-inch layer of clean sand. The sand layer shall be placed the same day excavation is completed.
5. Observation Well - A 4-inch diameter, rigid perforated vertical pipe shall be installed in the trench. The vertical pipe shall be securely and permanently attached to a base to prevent upward movement. The top of the vertical pipe shall have a secure removable cap. The original depth shall be permanently marked on the top of the observation well.
6. Geotextile - The sides and top of the trench shall be lined with geotextile. The bottom of the trench shall NOT be covered with geotextile.
7. Rock - Rock fill shall be clean, poorly-graded, uniform size crushed washed rock. Well-graded rock has less void space available for runoff storage and shall not be accepted.
8. Gravel Top Layer - The top layer of the geotextile shall be covered by 6 inches of gravel (0.75-inch diameter).

2.8 Sand and Organic Filters

Above-ground Austin Sand Filter and sand filtration chamber.

Description

Sand filters utilize a sedimentation chamber and a filtration chamber to treat stormwater. The first chamber (sedimentation) removes large particles from stormwater by allowing them to settle out of suspension, while the second chamber (filtration) removes finer particles by filtering stormwater through a bed composed of sand or a combination of sand and organic material overlying a drain system.

Sand filters provide good treatment for pollutants except nitrates. Since these facilities attenuate the peak flows of common storm events, they are expected to reduce the potential for downstream channel erosion.

Conditions Where Practice Applies

Sand filters can be applied on most types of sites, but are most often implemented on ultra-urban sites dominated by impervious area or where space is a consideration. Sand filters also achieve a relatively constant effluent concentration of 7.5 mg/L TSS regardless of influent concentration. Therefore, sand filters, if maintained frequently enough to prevent clogging, are effective at treating stormwater "hot spots" with atypically high particulate loads, such as commercial parking lots, fueling stations, auto recycling facilities, industrial rooftops, commercial nurseries, outdoor loading/unloading facilities, and vehicle or equipment washing facilities.

Sand filters are appropriate on sites where contamination of groundwater may be a concern. In most instances, sand filters are constructed with impermeable basin or chamber bottoms that help to collect, treat, and release runoff to a storm drainage system or directly to surface water with no contact between runoff and groundwater. Sand filters can be used in areas where a permanent pool cannot be maintained for a wet pond. Sand filters should not receive runoff from active construction areas and are not appropriate for continuously disturbed areas that could cause premature clogging of the sand/media bed.

The two most common types of sand filters used in the United States, the Austin Sand Filter (Figure 2.8.3) and the Delaware Perimeter Sand Filter (Figure 2.8.4). The Austin Sand Filter is built at or below grade and is most commonly used for larger drainage areas that have both impervious and pervious surfaces. Delaware sand filter systems are installed underground, and thus are most commonly used for highly impervious areas where land available for structural controls is limited.

Planning Considerations

Size and Condition of Contributing Drainage Area – Sand filters are best suited to treat drainage areas of up to 25 acres for Austin aboveground sand filters and up to 1 acre for Delaware perimeter or underground units. Aboveground sand filters have been used for drainage areas up to 100 acres, but require larger pretreatment basins, additional distribution of water across the filter bed, and/or more frequent maintenance to prevent clogging. Because of clogging concerns, sand filters should not be used on sites where soils are permanently disturbed, and no stormwater should enter the filter system while the site is under construction.

Slopes – Sand filters can be used on sites with up to 6 percent slope. Austin aboveground sand filters require an elevation drop (head) of about 4 to 8 feet to allow runoff to flow through the system, while Delaware Perimeter Sand Filters typically require only 2 feet of head. The top of the filter bed must be completely level and stormwater must enter the filtration chamber as sheet flow.

Climate – The filter bed and internal conveyance structures may freeze in aboveground and perimeter sand filters unless the filter bed is placed below the frost line. Alternative conveyance systems such as a weir system between the sediment chamber and the filter bed may prevent the filter bed from freezing in more mild cold climates.

Design Criteria

The design of sand filters can be altered to fit a variety of site constraints or community preferences. Due to this flexibility, several sand filter designs have been developed. This manual provides the design criteria for two common configurations of sand filters: the Austin Aboveground Sand Filter and the Delaware Perimeter Sand Filter. Other manuals should be consulted for other design variations. The design steps will generally follow those laid out in Figure 2.8.1 for both aboveground and perimeter sand filters.

1) Determine overall treatment volume (WQv)
2) Divert flows exceeding treatment volume
3) Size and configure sedimentation chamber
4) Size and configure filtration chamber
5) Size outlet structure

Figure 2.8.1 Overall Design Process

Sand filters are usually constructed inside a concrete shell or built directly into the terrain over an impermeable liner. Where possible, the filter bed should be constructed below the frost line to prevent freezing. Although most Austin Sand Filters are open, they have been installed underground in parking areas, along the perimeter of parking lots, and in medians or landscaped areas.

1. Determine the Treatment Volume (Water Quality Volume)

The water quality volume (WQv) is the volume of runoff that is treated by a sand filter system. The sand filter should be designed to capture and store the entire WQv within the sedimentation chamber with a weir, perforated riser, or other outlet structure used to gradually release the captured runoff into the filtration basin over a 24-hour period. The filtration basin is designed to provide a filtration time of no less than 24 hours (when the filter media is new) and no more than 40 hours (when the filter media is clogged and requires maintenance). A total drawdown time of 40 hours is used for facility design. The water quality volume is calculated using equation 1 below, adapted from Urban Runoff Quality Management (ASCE/WEF, 1998). This is required by the Ohio EPA NPDES general permit for construction activities.

$$WQv\ (ac\text{-}ft) = C * 0.75 * A / 12 \qquad \text{(Equation 1)}$$

Where:

C = runoff coefficient

A = area draining into the BMP in acres

The runoff coefficient, C, is calculated using the following equation or alternatively values provided in the current Ohio EPA NPDES general permit for construction activities.

$$C = 0.858i^3 - 0.78i^2 + 0.774i + 0.04 \qquad \text{(Equation 2)}$$

Where:

i = watershed imperviousness ratio, the percent imperviousness divided by 100

Note: The Ohio EPA NPDES stormwater general permit for construction activities requires that the water quality volume be increased by 20% for capacity lost over time due to sediment accumulation.

2. Divert Flows Exceeding Treatment Volume

In most cases flows into the sand filter are limited to the water quality volume (WQv). Therefore other measures may be necessary to meet flood control detention requirements either (1) by diverting all runoff exceeding the water quality volume to separate facilities or (2) by increasing the size of the sedimentation basin and placing a second outlet sized to meet flood control requirements above the stage of the water quality volume. Figure 2.8.2 shows a device that utilizes a weir to divert the water quality volume to a sand filter.

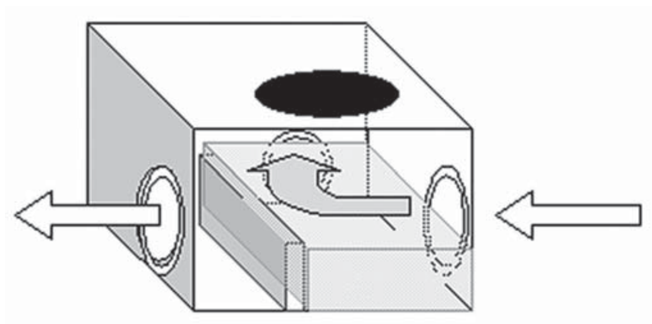


Figure 2.8.2 A weir inside the junction box of the storm sewer system diverts initial flows to sand filter.

3. Designing the Sedimentation Chamber (Basin)

The sedimentation chamber is the first stage of treatment within a sand filter. The chamber provides pretreatment of runoff by settling out coarser particles from runoff in order to prevent clogging and to reduce regular maintenance of the sand filter.

a) The Austin Sand Filter - Sedimentation chamber

The sedimentation chamber within an Austin Sand Filter is designed to completely empty between storms. This requires a somewhat larger size in order to minimize re-suspension of settled material, but also minimizes potential mosquito breeding conditions that exist within Delaware Perimeter Sand Filters and other designs that retain water between storms.

Basin Dimensions – The volume of the sedimentation basin equals the WQv plus an additional 20% of the WQv for sediment storage. The water depth in the sedimentation basin when full should be at least 2 feet and no greater than 10 feet. The minimum surface area of the sedimentation basin is determined by using the equation:

$$As = (1.2 * WQv)/(ds + freeboard) \qquad \text{(Equation 3)}$$

Where:

As = Minimum surface area of sedimentation chamber (cubic feet)
WQv = Water Quality Volume (cubic feet)
ds = Basin depth (feet)
freeboard = 0.5 feet

The sedimentation chamber should be configured so that it has a minimum length-to-width ratio of 2:1 between inlet(s) and the outlet, otherwise baffles may be necessary within the sedimentation chamber. A fixed vertical sediment depth marker should be installed in the sedimentation basin to indicate when 20% of the basin volume has been lost because of sediment accumulation.

Sedimentation Chamber Inlet – The WQv should be discharged uniformly into the sedimentation chamber at a velocity of no more than 2 ft/sec in order to maintain near quiescent conditions. A drop inlet structure is recommended to allow more efficient collection of sediment and other suspended solids that settle out within the sedimentation chamber. Energy dissipation devices may be necessary in order to reduce inlet velocity to 2 ft/sec or less.

Sedimentation Chamber Outlet – The outlet of the sedimentation basin conveys the WQv into the filtration chamber. The outlet structure should consist of a weir or a perforated riser pipe with a trash rack discharging to a weir acting as the inlet to the filtration chamber (Figure 2.8.3):

- Any weirs shall extend across the full width of the facility such that no short-circuiting of flows can occur.
- The riser pipe shall have a minimum diameter of 6 inches with four 1-inch perforations per row. The vertical spacing between rows should be 4 inches (on centers). To prevent clogging, it is recommended that the bottom half of the riser pipe be wrapped with geotextile fabric and that a cone of 1 to 3 inch diameter gravel be placed around the riser pipe.
- If a riser pipe is used to connect the sedimentation and filtration basins a valve shall be included to isolate the sedimentation basin in case of a hazardous material spill in the watershed. The control for the valve must be accessible at all times, including when the basin is full.
- Openings in the trash rack should not exceed one-third the diameter of the riser pipe.

Liners – For sedimentation basins built directly on the terrain of the site, they must be built on an impermeable liner, particularly in areas where groundwater protection is of primary importance. The liner may consist of either compacted clay with a hydraulic conductivity of 1 x 10-6 cm/sec or less, or nonwoven geotextile fabric meeting the specifications of ASTM D-751 and ASTM D-1682 and a minimum US Standard Sieve size of 80.

b.) The Delaware Perimeter Sand Filter Sedimentation Chamber

The sedimentation basin within the Delaware Perimeter Sand Filter system is usually a narrow 24" deep trough parallel to; and the same length and width as, the filtration basin, separated by a weir that runs the entire basin width with an elevation equal to the elevation of the top of sand in the filtration basin (see Figure 2.8.4). This weir results in a permanent pool 24 inches deep, the depth of the filtration bed, within the sedimentation basin. Although this dead storage serves to prevent the re-suspension of settled particulates, it may serve as a breeding ground for mosquitoes.

Sedimentation Chamber Surface Area – To meet Ohio EPA permit requirements, the WQv must fit within the volume of the sedimentation basin and the filtration basin between the top of the filter media and an overflow weir designed to divert flows in excess of the WQv to conveyance and/or detention facilities sized to meet local drainage criteria. The following equation may be used to calculate the surface area of the sedimentation basin:

$$A_s = WQv/2h - A_f \qquad \text{(Equation 4)}$$

Where:

A_s = Surface area of the sedimentation basin (square feet)

WQ_v = Water quality volume (cubic feet)

$2h$ = Maximum allowable depth of water over the filter (feet)

A_f = Surface area of the filtration basin (square feet)

The surface area of the sedimentation basin and the filtration basin are usually equal in a Delaware Perimeter Sand Filter, allowing the following equation to be used to determine the maximum allowable depth of water over the filter:

$$2h = WQv / 2^*A_f \qquad \text{(Equation 5)}$$

Solve this equation simultaneously with Equation 4 to calculating the surface area of the filter bed.

Establishing Basin Width and Length – Once the area of each chamber is calculated, the dimensions of the facility must be established. Although typical sediment trenches and filter trenches are 18 to 30 inches wide, site constraints dictate the width. In addition, other factors such as available grate widths also may dictate final widths. Standard grate width is 26 inches.

Floatable Control – The standard Delaware Sand Filter design does not provide a means to prevent floatables or hydrocarbon sheens from passing through to the filtration chamber. If installing a Delaware Sand Filter in a situation where floatables or hydrocarbons are a concern, long-term maintenance plans should reflect the increased maintenance needs of the sand filter. In addition, large storm overflow weirs should be equipped with a 10-gauge aluminum hood or commercially available catch basin trap. The hood or trap covers should extend a minimum of 1 foot into the permanent pool.

Dewatering Drain – A 6-inch diameter dewatering drain with gate valve should be installed at the top of filter bed elevation through the partition separating it from the clear-well chamber.

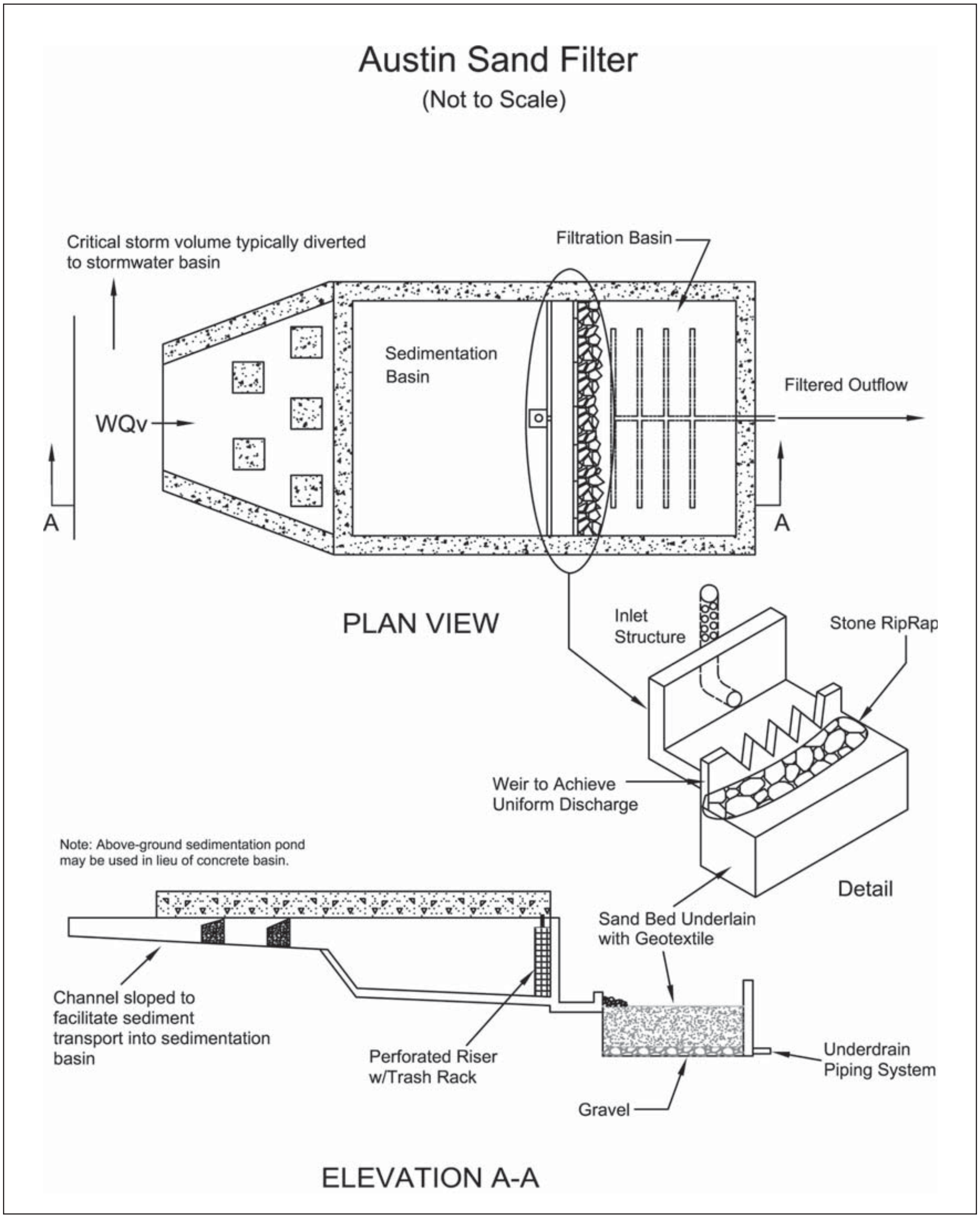


Figure 2.8.3 Austin Sand Filter, (City of Austin, TX. 1996).

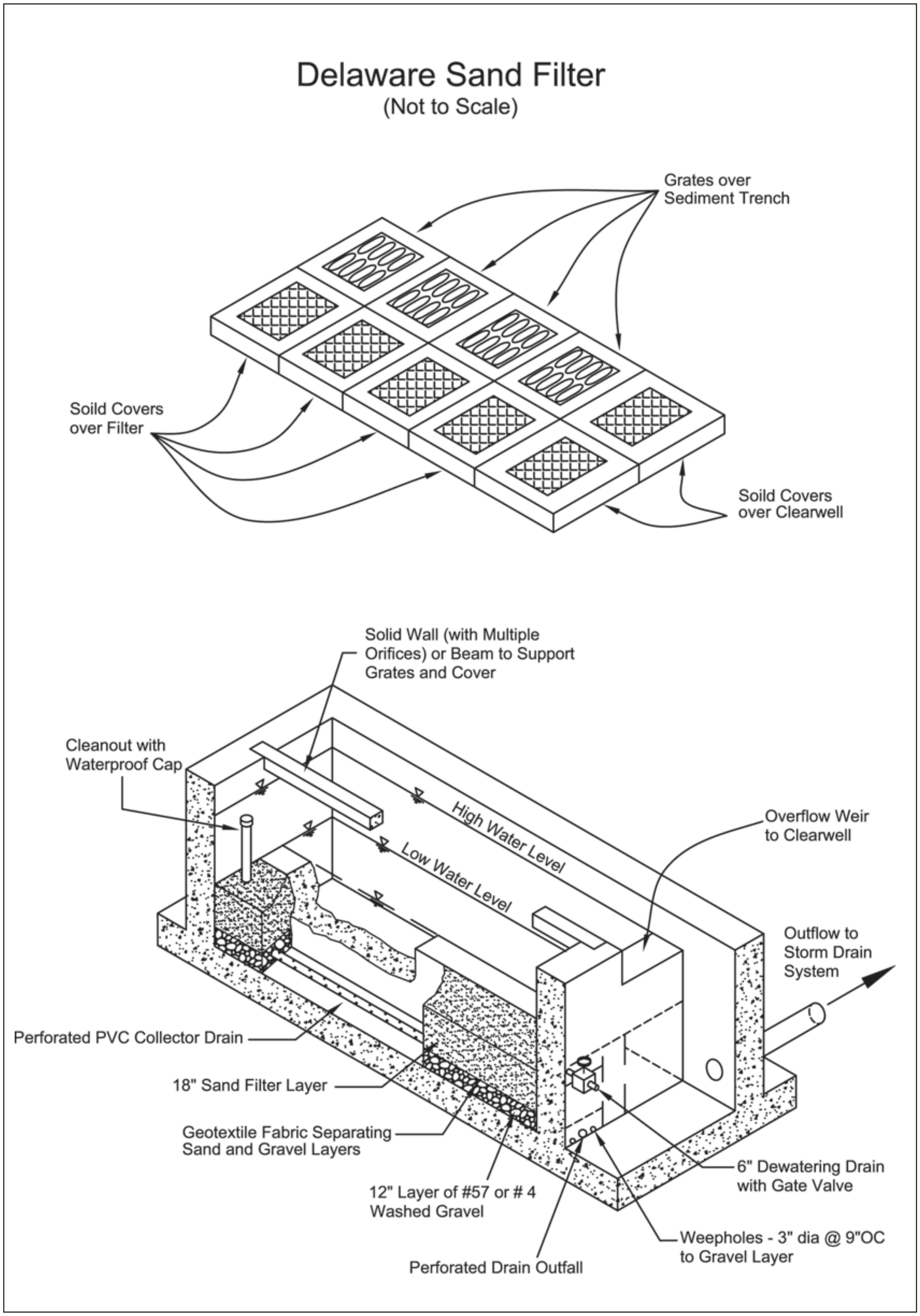


Figure 2.8.4 Delaware sand filter (City of Austin, TX. 1996).

4. Designing the Filtration Chamber

Once the WQv passes through the sedimentation chamber, it enters the filtration chamber where the stormwater passes through a sand filter for treatment. Surface area is the primary design parameter.

Filter Surface Area – The filter surface area is calculated using the following formula:

$$A_f = \frac{WQv * d_f}{k* (h+df) * t_f} \qquad \text{(Equation 6)}$$

Where:

A_f = Filter surface area ($feet^2$)
d_f = Sand bed depth (feet)
k = Coefficient of permeability for sand filter (feet/day)
= 3.5 ft/day for clean concrete sand (0.02" to 0.04" diameter) satisfying AASHTO M-6 or ASTM C-33
h = One-half the maximum allowable water depth over filter (feet)
t_f = Time required for runoff volume to pass through filter (days) or 1.67 days (40 hours) per Ohio EPA requirement

Filter Basin Inlet – Storm water must be spread uniformly across the surface of the filter media. To assure a uniform flow, stormwater must enter the filtration chamber using flow spreaders, weirs or multiple orifice openings, and the receiving end of the sand filter protected (splash pad, riprap, etc.) such that erosion of the sand media does not occur.

Sand Bed – The sand filter is constructed with at least 18 inches of sand overlying at least 6 inches of very coarse gravel (0.5 to 2 inch diameter). The sand and gravel media shall be separated by a permeable geotextile fabric meeting ASTM D-751 and ASTM D-1682, and the gravel layer shall be placed on drainage matting made of geotextile fabric meeting ASTM D-2434, ASTM D-1682, and ASTM D-1117. Figures 2.8.3, 2.8.4 and 2.8.5 present schematic representations of a standard sand beds.

Underdrain and Outlet Requirements – The underdrain piping consists of 4 inch diameter perforated PVC pipe (Schedule 40 PVC or greater), configured as a main collector pipe and, for Austin Sand Filters, two or more lateral branch pipes placed no more than 10 ft apart or 5 ft from the basin wall. Perforations should be 3/8 inch in diameter, with at least 6 holes per row and a maximum spacing between rows of perforations of no more than 6 inches. Each underdrain pipe should be wrapped in a geotextile fabric meeting ASTM D-751 and ASTM D-1682, with a minimum of 2 inches of gravel covering the top surface of the PVC pipe. Each pipe must have a minimum slope of 1% (1/8 inch per foot), and each individual underdrain pipe shall have a cleanout access location.

Weepholes – Weepholes between the filter chamber and the shell may be provided as a backup in case of underdrain pipe clogging. If used, weepholes should be 3 inches in diameter with a minimum spacing of 9 inches center to center. The openings on the filter side of the dividing wall should be covered to the width of the trench with 12-inch high plastic hardware cloth of 1/4-inch mesh or galvanized steel wire, minimum wire diameter 0.03-inch, number 4 mesh hardware cloth anchored firmly to the dividing wall structure and folded 6 inches back under the bottom stone.

Maintenance of Sand Filters

Filter systems require frequent maintenance. Two design considerations that can help reduce maintenance problems are:

1. Providing access to the filtering system
2. Addressing confined space issues for underground systems

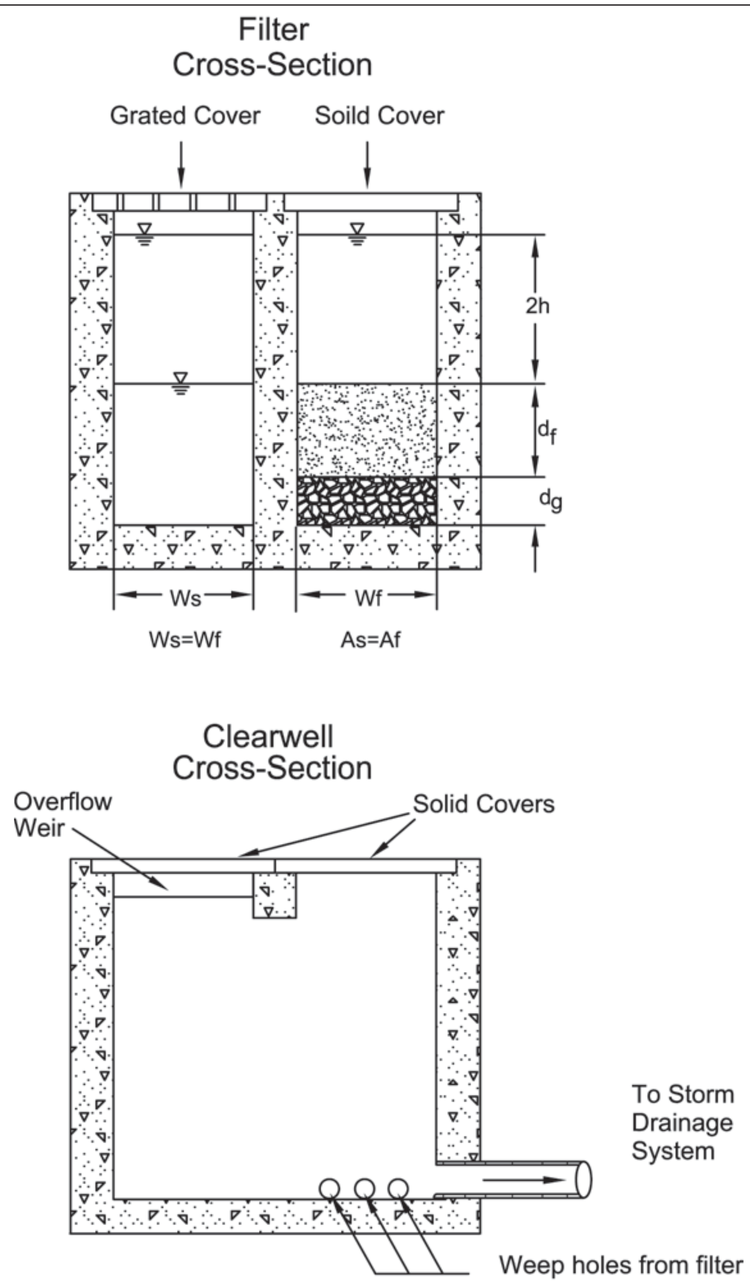
Where observation wells and grates are used, lifting rings or threaded sockets should be provided to allow for easy removal by lifting equipment. Access for the lifting equipment must be provided. Any long-term maintenance plan for sand and organic filters should include regular inspections for each of the following items:

Table 2.8.2 Typical maintenance activities.

Schedule	Activity
Monthly	Debris Removal Check for clogging and sediment accumulation on the filter surface – remove and place areas where clogging is occurring or likely If sediment chamber is more than half full of sediment, clean out Vegetation Control for surface systems (if applicable) • Mowing • Fertilization • Repair erosion
Semi-annual	Check for cracks and leakage Inspect, repair grates Replenish media
Annual and/or after major storms	Remove accumulated sediment from sedimentation chamber Rake and/or remove sediment from surface of filter bed Inspect spillways and repair if necessary

Delaware Sand Filter

(Not to Scale)



Where: Ws = Width of sediment chamber
Wf = Width of filter
As = Area of sediment chamber
Af = Area of filter
2h = Maximum ponding depth over filter
df = Depth of sand layer
dg = Depth of gravel layer

Figure 2.8.5 Delaware filter cross sections.

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2.9 Grass Filter Strip

Description

Grass filter strips, also known as vegetated filter strips, treat the water quality of small sheet flows from developed areas. They are uniform strips of dense turf or meadow grasses with minimum slope, best suited to accept diffuse flows from roads and highways, roof downspouts, and very small parking lots, usually prior to runoff being collected by swales, ditches or storm drains. They are also an ideal component of stream buffers or as pretreatment to a structural practice.

Dense turf creates a thick porous mat, which slows runoff velocity from small flows causing deposition and filtration of particulates. Other pollutant removal mechanisms are nutrient uptake, adsorption and infiltration. Grass filter strips are generally not very effective for treating soluble pollutants. Their overall effectiveness is highly variable depending on slope, the quality of turf, and flow rates. It is critically important to maintain sheet flow through the filter strip; otherwise the practice provides little to no treatment.

Conditions Where Practice Applies

Grass filter strips are an adaptable practice that often can be incorporated throughout a development site, allowing multiple use from turf areas. Grass filter strips, should not be used as the primary control practice to provide water quality treatment for a development site, particularly hot spots such as gas stations and junkyards, but can be used as a supplemental practice or as pretreatment when combined with another structural treatment practice.

Natural meadow areas also may be used for grass filter strips. Grass filter strips are most often located in landscaping areas around building and parking lot perimeters, in greenbelts or along conservation easements, and median strips in parking lots and streets. The site's topography must allow shallow slopes and sheet flow runoff through the filter strip.

Filter strips are a suitable practice to protect cold-water habitats as they typically do not warm runoff.

Filter strips are impractical in ultra-urban settings because they consume a large amount of space when compared to other practices. Filter strips typically consume an equal width to the impervious drainage area they treat.

Planning Considerations

Grass Filter Strips at the Source vs. Buffer Strips at the Resource

Grass filter strips are used as close as possible to the source of the runoff. They are integrated throughout a development site such as along the edges of parking lots. Buffer strips, on the other hand, are used adjacent to perennial and intermittent stream channels. Grass filter strips are planted to turf while buffer strips have diverse forest vegetation. Grass filter and buffer strips both treat sheet flow runoff but buffer strips also provide many additional functions important to the riparian system: shading, bank stability, leaf litter and detritus.

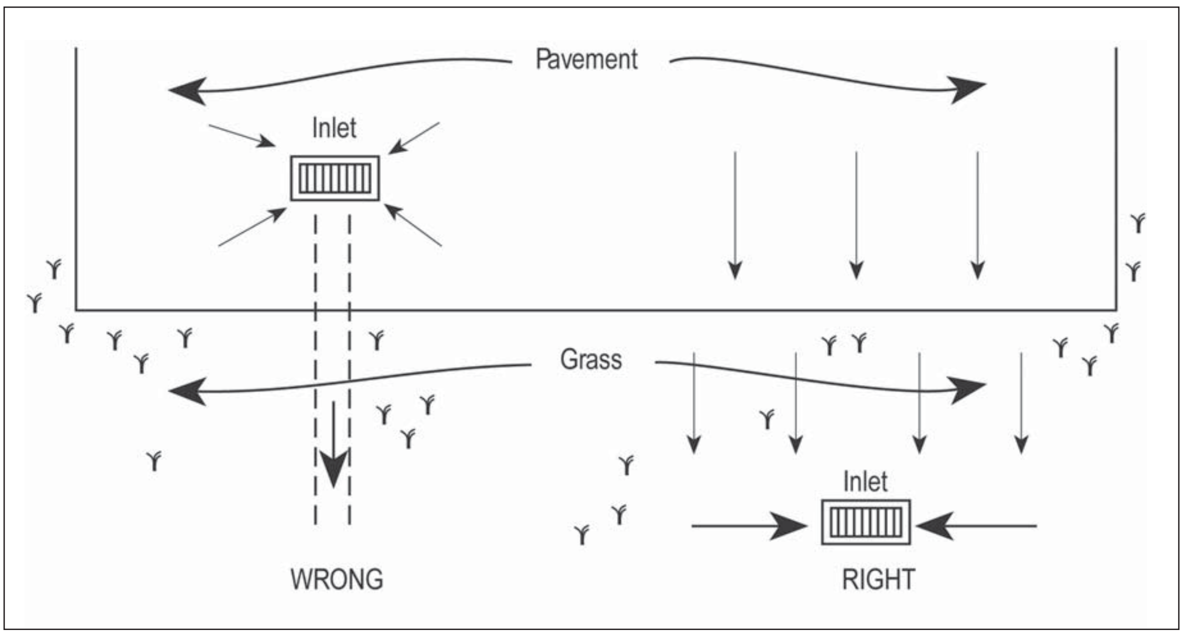

Figure 2.9.1 Runoff routed through grass filter strip before entering drainage system

Design Criteria

Siting Criteria

The filter strip should abut the contributing drainage area. If placed abutting a parking lot, devices that channelize flows into the filter, such as curb cuts and gutters should be avoided. In order to minimize soil compaction and to maintain quality dense vegetation, filter strips should not be located in areas expected to receive heavy pedestrian or vehicular traffic once the site is developed.

Drainage Area

The limiting design factor for grass filter strips is not the drainage area to the practice, but rather the length of flow leading to it. The length of flow cannot exceed the length at which sheet flow concentrates. As a rule of thumb, sheet flow from impervious surfaces will concentrate within a maximum of 75 feet, and 150 feet from pervious surfaces (Center for Watershed Protection, 1996). Thus, as a rule of thumb, a filter strip can treat 1 acre of impervious area per 580-foot length and 1 acre of pervious area per 290-foot length.

Slope

The slope of a grass filter strip should be as flat as possible. However, if standing water may create a nuisance, slopes should be sufficient to provide positive drainage. To avoid runoff converging into concentrated flows, slopes must be less than 5%. Filter strips that are 1% slope or flatter should be avoided unless they are built on very sandy or gravely soils. The top and toe of the slope should be as flat as possible to encourage sheet flow and prevent erosion.

Slope Length

A higher level of pollutant removal is achieved the longer the slope length (the distance water flows through a filter strip). Grass filter strips must have a minimum slope length of 25 feet, but should be designed to provide a slope length based on their slope within the ranges noted in the table below:

Table 2.9.1 Filter Strip Flow Length

Slope of Filter Strip	75% Particulate Trap Efficiency	90% Particulate Trap Efficiency
1%	25 ft	50 ft
2%	30 ft	120 ft
3%	40 ft	135 ft
4%	60 ft	170 ft
5%	75 ft	210 ft

Ground Water

Filter strips should be separated from ground water by at least 2 to 4 feet to prevent contamination and to assure that the filter strip does not remain wet between storms.

Soils

Filter strips will be less effective as the clay fraction of the soil increases, since this limits the infiltration of runoff associated with proper treatment. Filter strips are not suitable in very poor soils that cannot sustain a grass cover.

Assuring Sheet Flow

To assure that runoff remains as sheet flow through the filter strip, a grass or rock trench level spreader shall be used at the top of the slope. The level spreader must have a minimum depth and a minimum width of 1 foot. The level spreader shall be placed on a level contour. In addition to assuring sheet flow, the level spreader acts as a pretreatment device to settle out some sediment particles.

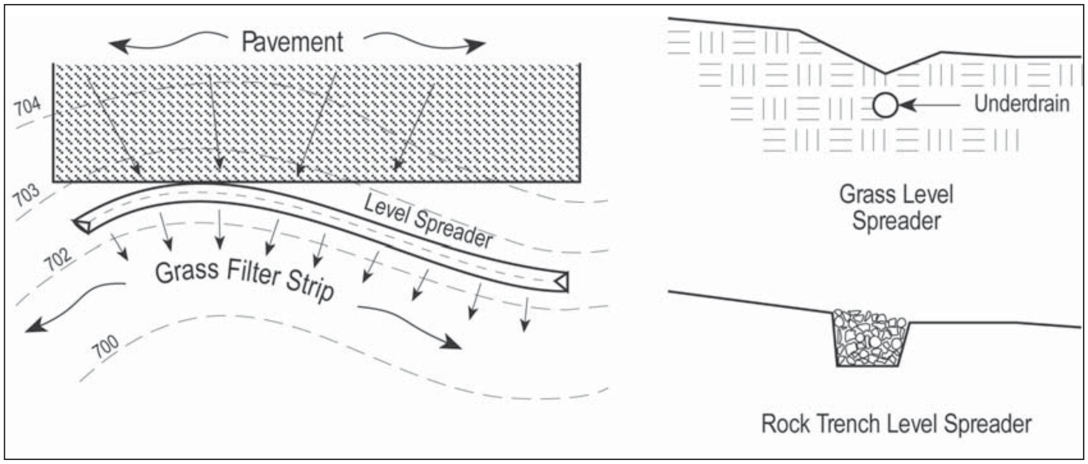

Figure 2.9.2 Grass filter strip with level spreader to distribute flow

Establishing Vegetation

Dense vegetation is critical to effective filter strips. Poor stands of vegetation may even result in a grass filter strip eroding and becoming a source of pollution. Soil preparation and planting is deserving of special attention (see Specifications for Permanent Seeding). When selecting vegetation for grass filter strips, select species that can withstand relatively high velocity flows and both wet and dry periods. A tool to select the appropriate vegetation based on site specific conditions is available on the internet from the USDA Natural Resource Conservation Service at: http://ironwood.itc.nrcs.usda.gov/Netdynamics/Vegspec/pages/HomeVegspec.htm

Some common grasses suitable for use in Ohio include perennial ryegrass, tall fescue, red fescue and kentucky bluegrass as well as canada wildrye, chinese silvergrass, orchardgrass, smooth brome, switchgrass, timothy and western wheatgrass. Filter strips can even provide a convenient area for snow storage and treatment. If used for this purpose, salt-tolerant vegetation such as creeping bentgrass should be selected.

Seeding of the filter strip should be completed no later than September 30th to assure sufficient vegetation by October 31st. Vegetation should be inspected within 30 days of seeding to assure that an adequate stand of vegetation has established. If an adequate stand has not been established by October 31st, temporary measures must be installed to divert stormwater flows around the filter strip until adequate vegetation and stabilization occurs. No stormwater flows should be directed to a filter strip with established vegetation until the contributing drainage area has been stabilized.

Pedestrian and Vehicular Traffic

Heavy use should be avoided to minimize soil compaction and maintain quality dense vegetation.

Maintenance

– Only a minimum amount of maintenance should be necessary to ensure continued functioning of grass filter strips.

– The most significant concern is gully formation from unexpected concentrated flows. If rills and gullies occur, they must be repaired and stabilized with seed or sod. Measures must be taken to eliminate the concentrated flow.

– Filter strips should be inspected annually to assure that the level spreader is not clogged and to remove built-up sediment.

– Grass within the filter strip should be maintained as lawn. Grass height should be about 3 to 4 inches. Vegetation must be kept healthy.

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Specifications
for

Grass Filter Strip

NOTE: See Specifications for Permanent Seeding.

1. Filter strips shall be graded to prevent runoff from concentrating. Depressions, ridges and swales shall be graded out to achieve a uniform slope having a level grade across the slope.

2. To assure that runoff remains as sheet flow through the filter strip, a level spreader shall be used at the top of the slope. The rock or grass level spreader must be placed on a contour, and shall have a minimum width and depth of 1 foot.

3. Soil compaction shall be minimized in the filter strip area. Work shall be performed only when the soil moisture is low.

4. A subsoiler, plow or other implement shall be used to decrease soil compaction and allow maximum infiltration. Subsoiling shall be done when the soil moisture is low enough to allow the soil to crack or fracture.

5. Because a dense vegetation is critical for effective filter strips, only a dense stand of vegetation without rills or gullies shall be acceptable. If rills or gullies form or if vegetative cover is not dense, a new seedbed shall be prepared and replanted.

6. The filter strip shall be seeded no later than September 30th to assure that vegetation establishes prior to the onset of winter weather.

2.10 Bioretention

Description

Bioretention practices are stormwater practices that utilize a soil media, mulch and vegetation to treat runoff and improve water quality for small drainage areas. Bioretention practices can provide effective treatment for many runoff quality problems such as total suspended solids, heavy metals, organic compounds, bacteria and nutrients (phosphorous and nitrogen) by promoting settling, adsorption, microbial breakdown, and nutrient assimilation by plants. Outlet configurations of bioretention practices can be altered in order to encourage exfiltration, enhance nitrogen removal and mitigate discharge temperatures.

A bioretention area consists of a depression that allows shallow ponding of runoff and gradual percolation through a soil media, after which it either exfiltrates through underlying soils or enters the storm sewer system through an underdrain system. Bioretention practices are sized to fully capture and treat common storm events (the water quality volume) whereas runoff volumes from larger events may be designed to bypass these practices.

Condition Where Practice Applies

A bioretention practice is generally applicable for:

- Limited contributing drainage areas, generally less than 2 acres.
- Broad water quality treatment, including temperature, suspended solids, metals and depending upon design characteristics, nutrients. A comparison of practices is provided in Chapter 1.
- Various land uses including highly impervious areas such as roadways, commercial areas, or parking areas, especially in traditionally landscaped areas such as cul-de-sacs or park-

ing lot islands.

- Sites with soils of sufficient hydraulic conductivity or a suitable outlet for an underdrain system to fully drain the practice in a period of 12 to 48 hours.
- Sites with sufficient fall between inflow point and outlet for the underdrain, (generally exceeding 3.5 feet). Shallower facilities are expected to reduce the effectiveness of treatment.

Bioretention practices are not applicable where:

- Continuous groundwater flow will prevent the basin from draining between storm events.
- Groundwater pollution potential is high due to high pollution loads or a high groundwater table.

Planning Considerations

Groundwater Concerns – There is an increased risk of groundwater pollution if there is not adequate separation between bioretention facilities and the groundwater table.

High groundwater may impede the proper functioning of the practice by consuming storage capacity or slowing drainage of the practice. Karst areas, shallow bedrock, a high groundwater or seasonally high groundwater table, or soils that allow surface water to bypass treatment through the soil media all increase the potential for groundwater pollution. A minimum 2ft of separation is recommended and a minimum 1ft of separation is required between the top of the water table and the bottom of the excavated bioretention practice. Separation may also be achieved by using an impermeable liner or a layer of compacted earth. Seasonal high groundwater should also be evaluated so it is sufficiently below (see above) the excavated bottom of the practice or able to be lowered sufficiently with perimeter drains.

Off-line or In-line with Major Flow – Bioretention practices may be designed off-line or in-line with runoff flow. Off-line facilities fill to capacity, and then are bypassed by additional runoff. Off-line design minimizes the potential for eroding mulch or other material from the practice during high flows. Off-line bioretention is typically surrounded by an earth berm to capture the required volume of runoff and utilizes the same opening for flow entering and exiting the practice. Figure 2.10.1 shows an example of such a facility. Numerous installed off-line bioretention facilities have shown how poor design or poor construction may cause the initial treatment volume to bypass inlets to the practice. Therefore careful design must be used to insure that runoff enters and fills the practice before bypassing.

In-line (also called on-line) facilities fill with the required volume of runoff then discharge excess flows through an overflow or outlet structure such as a drop inlet or weir. These facilities must be designed to safely route large storms through the practices without erosion in the facility or at the discharge location.

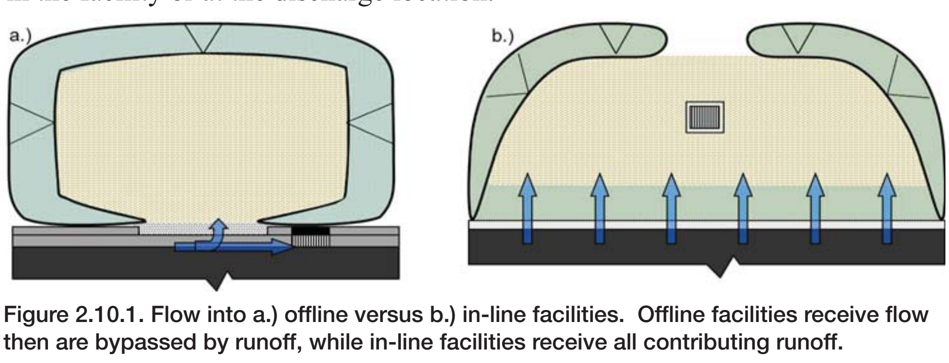

Figure 2.10.1. Flow into a.) offline versus b.) in-line facilities. Offline facilities receive flow then are bypassed by runoff, while in-line facilities receive all contributing runoff.

Suitable Soils for Infiltration and Establishing Need for a Designed Underdrain System – The bioretention practice must be designed so that the treatment volume will be drained between 12 and 48 hours either through infiltration into the soils under the facility, through an underdrain system, or through a combination of in-situ soils and an underdrain system. Facilities designed without an underdrain system shall have a qualified professional certify in-situ soils have the capacity to fully infiltrate the treatment volume within 48 hours. This certification shall include a description of the soil depth and horizons that correspond to the design elevations of the bioretention practice.

Setbacks to Prevent Water Damage - Appropriate setbacks from property lines, wells, septic systems, basements and building foundations shall be maintained to prevent damage to these systems or offsite areas. The following table provides recommended minimum setbacks.

Table 2.10.1 Minimum setbacks from important infrastructure.

	Setback Distance	
Feature protected by setback	Bioretention Utilizing Underdrain System	Bioretention Utilizing Suitable Soils For Infiltration
Property Line	2' (check with local requirements)	
Well	100'	
Septic System (including perimeter drain)	50'	
Building Foundations or Basements	10'	25'
Asphalt (parking, drives or roadways)	2' (check with local requirements)	

Long Term Maintenance and Easements - Since bioretention combines plant materials with the temporary storage and filtering of stormwater, more frequent regular maintenance is required than for other more traditional stormwater facilities. Designs shall include easy access for maintenance as well as an appropriate plan of operations and maintenance that considers the spectrum of activities described later in this standard. A legal and enforceable maintenance agreement shall be in place and executed. Although many bioretention facilities are located on private property and will be privately maintained, the area shall be placed in a drainage easement to permit public access if maintenance should be necessary. For residential developments, additional measures such as educational materials and deed restrictions may be necessary to prevent alterations that would affect the use or diminish the effectiveness of the bioretention practice.

Filter Bed Area - Bioretention facilities may require more area than some other stormwater treatment practices. Generally the surface area of the filter bed will be between five and ten percent of the contributing impervious area.

Slope and Effect of Curbing - Designers must consider the effect of curbing around the bioretention area on the design and construction of side slopes and the filter bed. Curbing may steepen side slopes in some areas and compel contractors to fill areas of the filter bed. Consider wheel stops that allow sheet flow, lower curbing or detailing exact grading on plans to prevent problems.

Construct Bioretention after Site Stabilization - Bioretention facilities shall be constructed after all other areas of the drainage area have been constructed and finally stabilized. That is, sediment-laden runoff from construction shall not be allowed to pass through the practice. Runoff from actively eroding sites will cause the premature failure of bioretention facilities. Avoid using a bioretention facility as a sediment trap or basin. If they must be used to capture construction site sediments, excavation should leave the trap or basin bottom at least 12 inches higher than the planned bioretention bottom elevation. After construction is finalized they may be excavated down to the final elevation after water and sediments have been removed. These measures will help to protect the infiltration capacity of the underlying soils.

Design Criteria

Water Quality Volume - All bioretention practices shall be designed to treat the water quality volume (WQv) by initially ponding that volume and allowing it to infiltrate through soil media within the practice. Bioretention practices have a target drawdown time of 24 hours for the surface ponding area. Drawdown time may be controlled by the soil media (typically), by an orifice on the underdrain or by the the rate of infiltration into in-situ soils under the practice.

Incorporating Additional Objectives - Design of bioretention practices will vary depending on the water quality objectives, the potential for groundwater recharge, and the potential for groundwater pollution. While all bioretention practices provide filtration through the soil media, the following conditions and design variations may enhance or limit the infiltration of water into in-situ soils, or enhance denitrification at the bottom of the practice.

In-situ Soils Suitable for Infiltration – Where in-situ soils can fully infiltrate the water quality volume within 48 hours and where groundwater pollution potential is low, exfiltration may be used as the primary drainage for the bioretention practice. Although this situation may be designed without an underdrain (Figure 2.10.2a), an internal water storage layer provided with a drain near the top serves as a backup to natural exfiltration (Figure 2.10.2b). Systems designed without an underdrain may not be used where extensive ponding of water above the practice will cause damage. Infiltration capacity of the soils shall be tested by a qualified professional.

Limited Infiltration and/or Enhanced Nitrogen Treatment - (Limited infiltration soils = $0.05 \leq Kfs \leq 0.5$ in/hr.) This design provides an internal water storage (IWS) layer below the upturned outlet of the underdrain pipe. This standing water zone (see Figure 2.10.2b and option 1 of 2.10.3) holds water and extends opportunity (both in time and quantity) for exfiltration. This layer also acts as a anoxic zone that encourages denitrification, that is, the conversion of nitrate to nitrogen gas, reduction in nitrogen discharge, and thus is an aid in preventing eutrophication of receiving waters. This design is expected to provide better than 40% and perhaps as high as 80% mass removal of nitrogen from surface runoff.

Low Infiltration In-situ Soils – For sites having in-situ soils with low permeability (clayey subsoils with $Kfs < 0.05$ in/hr), a standard underdrain bedded in a gravel layer provides the primary drainage for the practice (Figure 2.10.2c and Figure 2.10.3c). This configuration may be most appropriate for hydrologic soil group (HSG) D soils.

Impermeable Liner – For areas with a high water table, karst, shallow bedrock or high pollution loads, an impervious liner separates the entire practice from in-situ soils and the water table (Figure 2.10.2c). This design also relies on the underdrain system as the primary drainage. This is appropriate where heavy pollution is expected and/or where groundwater must be protected.

For sand, loamy sand, and sandy loam subgrade soils with $K_{fs} \geq 0.5$ in/hr.

For loamy or silty soils with $0.05 \leq Kfs \leq 0.5$ in/hr.

For clayey soils with $K_{fs} \leq 0.05$ in/hr. Some added sump volume may be acceptable on soils with K_{fs} = 0.02 - 0.05 in/hr.

For situations, where interaction with groundwater and surrounding soils must be limited.

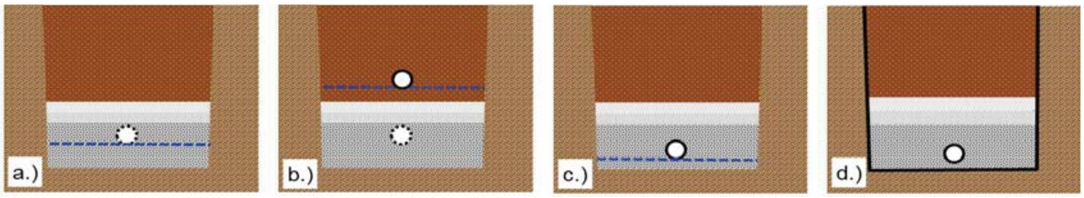

Figure 2.10.2 Underdrain configurations in typical bioretention cross-sections (blue dashed line designates water available for infiltration. From left to right:

a.) Bioretention with soils suitable for infiltration (underdrain optional).

b.) Bioretention with an internal water storage (IWS) layer that has been raised into the soil media for denitrification. An IWS will provide extra storage for infiltration.

c.) Underdrain placed for poorly drained soils.

d.) Lined bioretention cell.

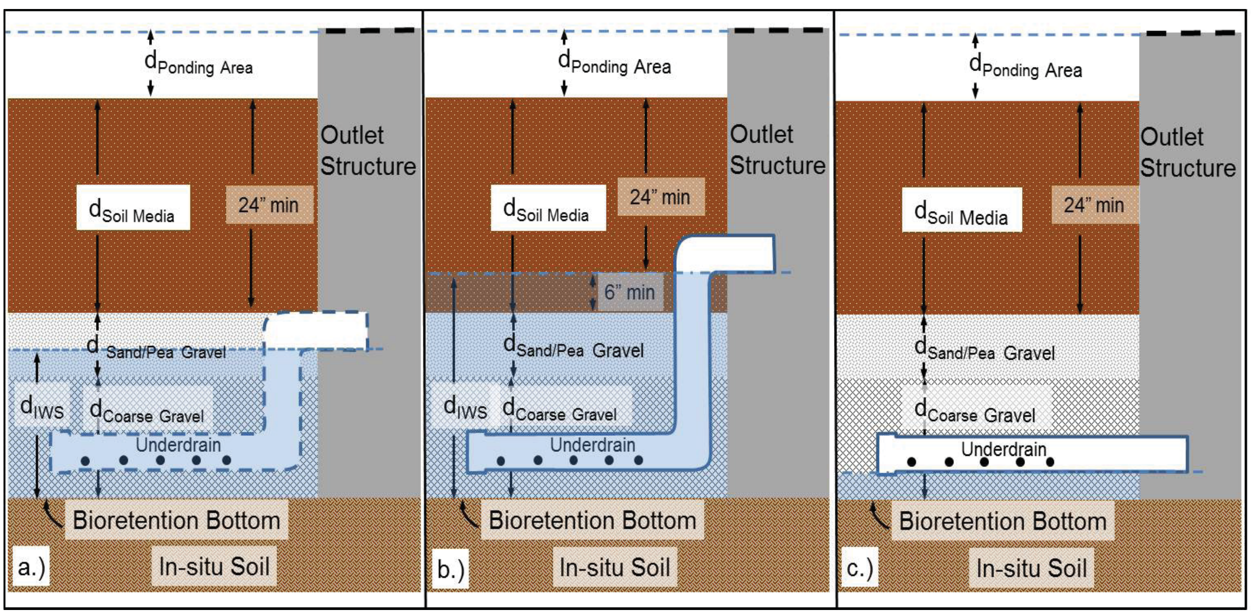

Figure 2.10.3 Comparison of different underdrain and internal water storage configurations. These should be based on the soil properties and the design objectives. The figures labeled a.), b.) and c.) correspond to the same labels in figure 2.10.2.

a.) A bioretention area with soils suitable for infiltration may or may not require an underdrain. The internal water storage (IWS) layer should be sized to hold a volume that is equal or greater than the water quality volume.

b.) Bioretention with an internal water storage (IWS) layer for increased infiltration or for treating nitrogen. Raising the upturned elbow so that at least 6 inches of the IWS is in the soil media creates conditions for denitrification.

c.) Underdrain placed with a minimum of three inches of cover and three inches of bedding. This design still allows some minimal water storage for infiltration even on poorly drained soils.

Area Dimensions – The filter bed area typically will have a minimum 10 foot width though there are scenarios, especially in densely urban areas, where narrower bioretention areas make sense in order to take advantage of available space in parking lot islands, curb bump-outs, or landscape planters. Basin sides slopes, and pretreatment and conveyance areas, may increase the overall area dedicated to the practice and may affect slope of the filter area.

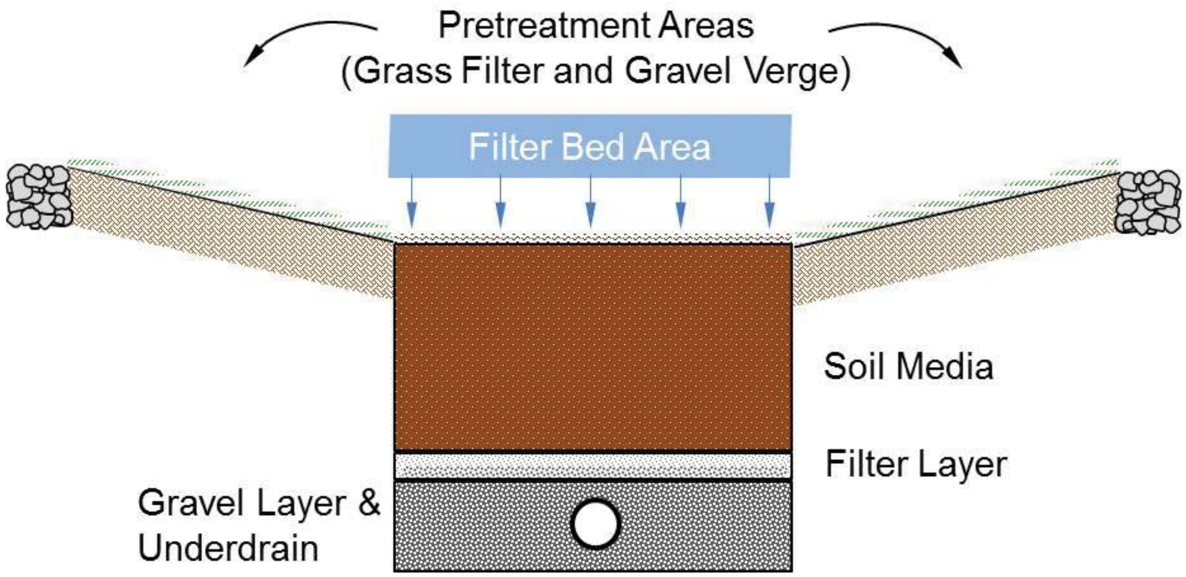

Figure 2.10.4 Components of Bioretention

General Components of Bioretention Practices

1. *Pretreatment Area* – Pretreatment is necessary to ensure long-term function of bioretention practices. High sediment loads cause clogging of the bioretention surface and failure of the practice. Pretreatment is designed to capture excessive sediment before it reaches the filter bed area and to dissipate energy so that flows into the practice don't erode adjacent soils or scour the filter bed. Pretreatment options vary based on whether flow is concentrated or enters the practice as sheet flow. Ideally, paved areas will be directed to the bioretention practice as sheet flow. For many bioretention areas, both types of pretreatment are necessary. The following pretreatment requirements apply:
   a. Sheet flows from paved areas shall use a gravel verge (a shallow stone-filled trench) at the edge of the pavement to dissipate energy and spread flow onto a grassed filter at least 10 feet long with 4:1 or flatter sideslopes (see Figure 2.10.4).
   b. For concentrated flows, the discharge must pass through either a grass swale or a pretreatment forebay. The grass swale must be at least 20 ft in length with a discharge of 1 fps or less for the 1-year 24-hour storm event. The forebay(s) must be sized to capture at least 20% of the WQv. Concentrated flows into the grass swale or forebay shall have an apron stabilized with appropriately sized riprap/stone.

2. *Filter Bed and Ponding Area* - The bioretention practice is designed to capture and temporarily store the entire water quality volume (WQv) so that it will infiltrate through the filter media. The ponding depth for the WQv should be less than or equal to 12 inches to ensure the WQv drains in a timely fashion (~24 hr) in preparation for the next runoff event. The depth of ponding is controlled by the height of the overflow structure or the berm containing runoff. [Note: Additional storage can be included above the WQv, with appropriate outlet, to achieve additional volume reduction or to help meet peak discharge requirements - see sections below.]

Minimum size of the filter bed:

For situations **where impervious areas exceed 25% of the contributing drainage area**, the filter bed area shall be a minimum of 5% of the contributing impervious area.

Example -

Contributing Drainage Area, A_{da} = 1.49 Ac = 65,000 ft^2

Impervious Area, A_{imp} = 0.57 Ac = 24,800 ft^2

Impervious Percentage, $I = (A_{imp}/A_{da})*100 = (24{,}800\ ft^2/65{,}000\ ft^2)*100 = 38.2\%$

Since I = 38.2% is greater than 25%, then

$A_{filter\ bed} = 0.05*A_{imp} = 0.05*24{,}800\ ft^2 = 1240\ ft^2$ (the minimum filter bed area)

For situations **where impervious areas are less than 25% of the contributing drainage area,** the filter bed area shall be at least equal to the WQv divided by the one foot maximum ponding depth.

Example -

Contributing Drainage Area, A_{da} = 1.49 Ac = 65,000 ft^2

Impervious Area, A_{imp} = 0.28 Ac = 12,200 ft^2

Impervious Percentage, $I = (A_{imp}/A_{da})*100 = (12{,}200\ ft^2/65{,}000\ ft^2)*100 = 18.8\%$

Because I = 18.8% is less than 25%, then $A_{filter\ bed}$ = WQv/1 ft

$WQv = C*P*A = 0.164*(0.75\ in)*(65{,}000\ ft^2)*(1\ ft/12\ in) = 666\ ft^3$

$A_{filter\ bed} = WQv/1\ ft = 666\ ft^3/1\ ft = 666\ ft^2$ (the minimum filter bed area)

3. *Mulch* – If the bioretention area is not vegetated with dense turf, a minimum 3 inch layer of coarse shredded hardwood mulch shall be placed around plants and over the planting soil. Besides protecting the filter bed surface from erosion, the mulch creates an organic layer conducive to filtering, capturing and degrading pollutants, and promoting biological growth. Pine mulches and fine or chipped hardwood mulches may not be used since they will float and move, blocking drainage or leaving the area with high flows.

4. *Planting Soil* – The planting soil filters the treatment volume, detains runoff in the available void space and provides a media for plant growth and a biological community. Much of the pollutant removal occurs in this zone due to filtering, microbial activity, ion exchange, adsorption and plant uptake. The planting soil (an engineered soil media) shall be at least two feet deep and up to four feet in depth (settled) depending upon the planned vegetation. Greater depth is necessary to accommodate the root ball of trees planted in bioretention facilities. Soils and soil mixes must be certified by a qualified laboratory (1 test per 100 yd^3 of soil) and have the following attributes:

- Texture class: loamy sand. Having no less than 80% sand and no greater than 10% clay considering only the mineral fraction of the soil.
- pH range: 5.2 - 8.0
- Soluble Salts: 500 ppm maximum.
- Decomposed organic matter: 3-5% by weight [Note: this translates to 8-20% organic matter by volume. See note on "Creating a Suitable Soil Media" below.]
- Phosphorus: phosphorus of the planting media should fall between 15 and 60 mg/kg (ppm) as determined by the Mehlich III test. For sites in watersheds with a phosphorus TMDL or sites with high phosphorus loads, the phosphorus content of the planting media should fall between 10 and 30 mg/kg as determined by the Mehlich III test.
- Sand added shall be clean and meet AASHTO M-6 or ASTM C-33 with a grain size of 0.02-0.04" inches.

Note: Portions of this text regarding creating soil media is being considered for revision. It appears that a sand-soil-compost ratio of 5-1-2 (maybe 5-1-3) may be a better starting point to reach the specified attributes above. Input is welcome.

John Mathews 7-9-14

Creating Suitable Soil Media - To meet the above soil media criteria, the following mix (by volume) is recommended as a starting point:

Sand: 7.5 parts clean sand (i.e., ASTM C-33 or equivalent, < 1% passing No. 200 sieve)

Native Soil: 1.5 part (loam, silt loam or clay loam texture)

Decomposed Organic Matter: 1 part (leaf compost, pine bark fines, mulch fines, etc.)

Based on testing, experience and native soil characteristics the sand, soil or organic matter content can be adjusted to achieve the desired mix. The soil mix supplier should pre-test the sand, native soil and organic matter to evaluate their phosphorus content. The soil mix supplier must present a soil test showing the planting media meets the criteria above.

5. *Filter Layer* - The filter layer is composed of a layer of sand over a layer of pea gravel and is required to prevent fines from the planting soil migrating down through to the underdrain or to the subsoil below the practice.
   - Three inches of clean medium concrete sand (ASTM c-33) over three inches of #8 or #78 stone (pea gravel).

6. *Gravel Layer and Underdrain System* - A gravel bed consisting of # 57 washed stone (excluding recycled concrete) shall be provided as drainage media and bedding material for underdrain pipes and as the water storage reservoir in whole or as a part (with 6 inches of soil media) for the purpose of denitrification. The gravel layer shall generally be 10-12" thick with a minimum of 3-in. of gravel provided above and below underdrain pipes. The thickness of the gravel layer (or sump) below the drain may be increased to promote infiltration into the underlying soil.

Page updated on 3-3-14

Underdrains shall be a perforated pipe capable of withstanding the expected load above and exceeding the drainage capacity of the planting soil layer. The following requirements apply to underdrains:

- The underdrain system shall be placed level or on a positive slope.
- Underdrain pipes shall be a minimum 4-in. diameter perforated PVC pipe with the holes oriented downward.
- Underdrains are placed within a layer of # 57 washed gravel, having a minimum of 3-in. of gravel above and 3-in. below the pipe.
- Underdrains shall be placed depending upon the purpose of the reservoir created:
    - o For promoting infiltration into appropriate in-situ soils, underdrains are outletted at a higher elevation from the gravel layer either by raising the underdrained or utilizing an upturned elbow. Provide suitable gravel thickness to create an internal water storage (IWS) layer (temporary storage sump) capable of storing the entire water quality volume. See the figure below.
    - o For treating nitrogen, an upturned elbow is also used to raise the outlet of the underdrain and thus create an anoxic zone for denitrification. Ponding water into the bottom six inches of soil media is necessary for this to occur and will increase nitrogen removal by the practice. Gravel depth is determined by the volume of water targeted for anaerobic treatment. See the figure below.
- Underdrain pipes shall end with an elbow or a capped tee with a vertical pipe providing observation and/or cleanout at the elevated end of the pipe. Observation/cleanout pipes shall consist of a minimum 4 inch diameter vertical non-perforated PVC pipe extending to the surface of the practice and sealed with a removable watertight cap.
- Underdrains shall drain to an existing drainage system or other suitable stable outlet having positive drainage.

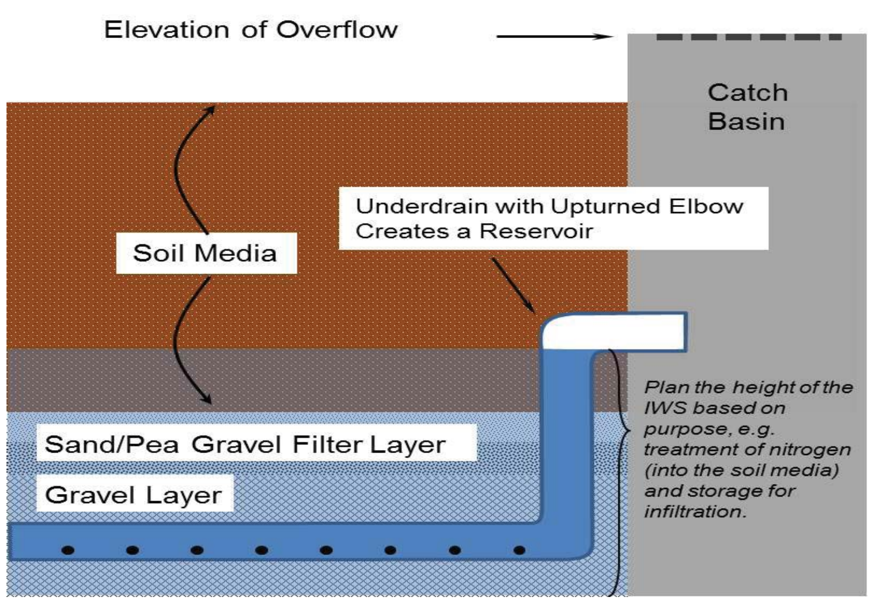

Figure 2.10.5 Bioretention with an underdrain and reservoir for increased infiltration. The reservoir or internal water storage (IWS) is created by using an upturned elbow. An orifice can also be added to modify the drain time through the filter media.

7. *Overflow, Tailwater and Routing* - Bioretention facilities shall have a means of discharging runoff that exceeds the capacity of the practice (in a non-erosive manner). This will be a drop inlet or weir set at the maximum ponding elevation of the treatment volume (WQv). In contrast, off-line facilities collect runoff until the ponding area fills, then are bypassed by additional storm flows. As with all stormwater practices, the designer must evaluate and account for potential tailwater conditions in the storm sewer or receiving stream.

   The bioretention practice is going to perform as intended, and most predictably, when the underdrain outlet is free draining (i.e., not subject to tailwater conditions where the underdrain outlet would be fully or partially submerged). However, bioretention practices are part of the larger stormwater management or drainage network of the development site. Having the outflow rate of the bioretention practice reduced due to increased head at the outlet is likely to have minimal negative impacts. However, any scenario in which water from the larger drainage network (such as a detention basin, a receiving stream or lake, or a storm sewer) is backed into the bioretention cell by having a higher head at the outlet than is present in the bioretention practice should be avoided. From a practical standpoint, the engineer might use the following rules of thumb when checking for back flow into the bioretention practice from tailwater/surcharge in the drainage network:

   - the bioretention practice should be designed such that the tailwater elevation does not exceed the elevation of the internal water storage zone for the 1-year, 24-hour event;
   - the bioretention practice should be designed such that the tailwater elevation does not enter the top 12 inches of planting media for the 10-year, 24-hour event.

8. *Planting Materials* – Species planted in bioretention practices should be adapted to the region, pollution tolerant, and able to survive the variable moisture conditions. Most plants should be facultative (found equally in wetland or upland conditions) though some species found in either environment may be acceptable. Native and non-invasive plants shall be used. Turf is an option if it can withstand the duration of ponding.

   Select plants that in a mature condition will be appropriate to the depth of soil and the underdrain system. For examples, trees may be selected if the planting soil will be at least 4 inches deeper than the root ball of the selected trees. Trees and large shrubs will require staking to prevent being dislodged by wind. It is recommended that a qualified landscape architect, horticulturalist, or native plant dealer be consulted during the design of the planting plan.

Design Checklist

1. Compute water quality volume (WQv). _____

WQv = C * P * A / 12, where:

WQv= water quality volume in acre-feet

C = runoff coefficient (Use formula below or coefficient from Ohio EPA NPDES permit)

Planned Site Imperviousness (i) _____ (e.g. for 80% imperviousness use 0.8)

$C = 0.858i^3 – 0.78i^2 + 0.774i + 0.04$

C = _____

P = 0.75 inch precipitation depth

A = area draining into the BMP in acres _____

2. Compute critical storm detention requirements. Substitute local requirements if they differ from the critical storm method.

Design Storm	Peak Discharge Rate (cfs)	24-hour Runoff Volume (show units)		Percent Increase	Design Discharge (cfs)
		Pre-Development	Post- Development		
1-year					
2-year					
5-year					
10-year					
25-year					
50-year					
100-year					

Critical Storm _______ Design Discharge ________

3. Determine whether bioretention is an appropriate stormwater practice for the area.

- Limited drainage area (generally <2 acres)
- Outlet for an underdrain and or soils of sufficient hydraulic conductivity to fully drain the practice in a period of 12 to 48 hours.
- Sites with sufficient fall between inflow elevation to outfall (generally exceeding 3.5 feet). Shallower facilities are expected to reduce the effectiveness of treatment.
- Consider whether peak discharge requirements will be managed at the bioretention practice and whether these stormwater detention needs make bioretention infeasible.
- No continuous groundwater flow or seasonal high groundwater table above the practice bottom, or perimeter drains are sufficient to lower seasonal high groundwater table.
- Low potential for groundwater pollution (high pollution loads or high groundwater table). A liner may be used in areas with high pollutant loads or high groundwater table.
- Can meet setback requirements found in Table 2.10.1

4. Additional local conditions or criteria affecting design:

5. Determine the size of the bioretention filter bed area. The surface area of the filter bed is determined based upon site imperviousness and the ponded area needed to capture the water quality volume (WQv). For sites where impervious areas are greater or equal to 25% of the total drainage area, then the minimum filter bed area is equal to 5% of the contributing impervious area. For sites where impervious areas are less than 25%, then the filter bed area shall be at least equal to the WQv divided by the maximum ponding depth (≤ one foot). The WQv divided by the design depth provides the minimum surface area of the filter bed. Actual ponding of the WQv will be shallower as side slopes allow ponding over a larger bowlvolume.

Where the drainage area is ≥ 25% impervious area, the filter bed area shall be at least 5% of the contributing impervious area.

Where $A_{da} \geq$ 25% impervious, then $A_{filter\ bed} = 0.05 * A_{imp}$

Where the drainage area is < 25% impervious area, the filter bed area shall be the WQv divided by the maximum ponding depth (1 foot).

Where A_{da} = < 25% impervious then $A_{filter\ bed}$ = WQv/1 ft max. depth or other desired depth

6. Check to see that drain time is within the required parameters (12-48 hours):

7. Determine practice dimensions and design depths/elevations. The landscaped ponded area shall be a minimum of 10 feet wide with the length generally exceeding 2:1 (length:width).

- Width _____ • Length _____ • Ponding depth ______
- Overflow catch basin or weir
- Mulch depth 3”
- Soil media depth (generally 2 – 4 feet deep)
- Sand layer _______ • Pea gravel _______
- Gravel layer _____ • Cover over underdrain _____ • Diameter of underdrain ____
  - Underdrain invert elevation (at catch basin) ______
  - Depth of gravel layer beneath underdrain ______
- Liner (only for potential groundwater pollution)

8. Design stable conveyances into the practice. Off-line practices will need to have flow diverted.

- Flow diversion structure.
- Curb cuts or openings, rock channel protection.
- Slotted curb diversion in which flows exceeding WQv bypass the bioretention practice and are routed to other required stormwater detention practices.
- Overflow catch basin inlet.
- Other.

9. Pretreatment. Depending upon whether flow is concentrated or sheet flow, specify the devices used to dissipate runoff energy and to capture excessive sediment or other pollutants/trash before water is ponded. The plan and cross-section should show these devices and their dimensions.

- Stone trench/gravel verge.
- Grass filter strip.
- Grass channel.
- Forebay.
- Other.

10. Gravel layer and underdrain system

- No underdrain. On-site soils are suitable for infiltration. Tested rate of infiltration or hydraulic conductivity at the excavated depth ____.
- Upturned elbow or underdrain above gravel for internal water storage volume.

  Available water storage volume = volume of gravel x porosity (assumed 0.35 for #57 gravel)
- Standard gravel layer and underdrain system. Minimum 3" of gravel above and below the underdrain.

11. Emergency overflow. Conveys larger flows by or safely through the practice without erosion.

12. Landscaping plan. Show locations of plantings on a plan view and the associated quantities of suitable native plants.

Construction Issues

1. **Timing of Construction -** Construction of bioretention practices shall take place after land grading is complete and the contributing drainage area has been stabilized. Construction may take place if the entire contributing area can be effectively diverted until construction is complete and fully-vegetated cover protects all soil areas. Construction shall not occur during periods of precipitation since clogging of soils, bedding, filter or planting media may occur.
2. **Excavation, Soils and Liners -** Excavate the trench to plan dimensions being careful to protect in-situ soils by avoiding compaction of the trench with equipment or foot traffic. An initial 2-3" layer of uniform construction sand will help to avoid this impact. Some smearing of soils at the final grade will occur if a bucket without teeth is used. If this smearing occurs, it shall be remediated by fracturing a few inches deep with an appropriate tool. Bioretention lined with plastic shall use a minimum 30-mil liner and take measures to avoid puncture of the liner.
3. **Planting Soils -** Soils must be tested by a certified laboratory to insure they meet required specifications. Documentation of certification/testing shall be available onsite to site inspectors. The planting soil shall be placed in 12 inch lifts and lightly settled by gentle soaking with water (to promote settling). Planting soil should be placed to a depth approximately 5% higher than finish grade to allow for settling.
4. **Mulch -** Place mulch once sufficient settling of the planting soil has occurred in order to avoid excess compaction. Bioretention vegetated with turf shall be sodded or planted and provided with straw mulch cover as soon as final grade is reached.
5. **Vegetation -** Grassed filter strips should be sodded rather than seeded. Trees and tall shrubs subject to being thrown by wind must be staked to remain upright.

Maintenance

Proper functioning of a bioretention practice is dependent on the planting soil continuing to drain and plant survival. Most maintenance activities influence these goals. Maintaining the pretreatment area and minimizing erosion will extend the function of the planting soil. Bioretention areas are a landscaped feature of a site and regular attention to the plants is necessary. Take measures to insure winter snow plowing does not pile snow on trees or shrubs in the landscaped ponding area.

Over time (3-10 years); fine sediments may accumulate in the top few inches of planting soil. This is expected and can be corrected by replacing a portion of the planting soil or replacing all the planting soil and the filter layer until better permeability is achieved.

Activity	Schedule
Water Plants	As necessary during first growing season
Prune and weed plants for appearance	As needed
Inspect & replace poorly suited or diseased plants	As needed
Check for erosion or deposition in pretreatment and bioretention areas; Clean out and repair damaged areas	Semi-annually
Inspect facility for salt damages	Monthly
Remove litter and debris	Monthly
Add and/or replace mulch	Annually
Test soil and adjust as necessary to maintain in 5.2- 8.0 pH range	Biannually
Check planting soil and filter layer for clogging, replacing nec. portions	2 –10 years/ As needed

Table 2.0.2 These maintenance activities are suggested as a minimum.

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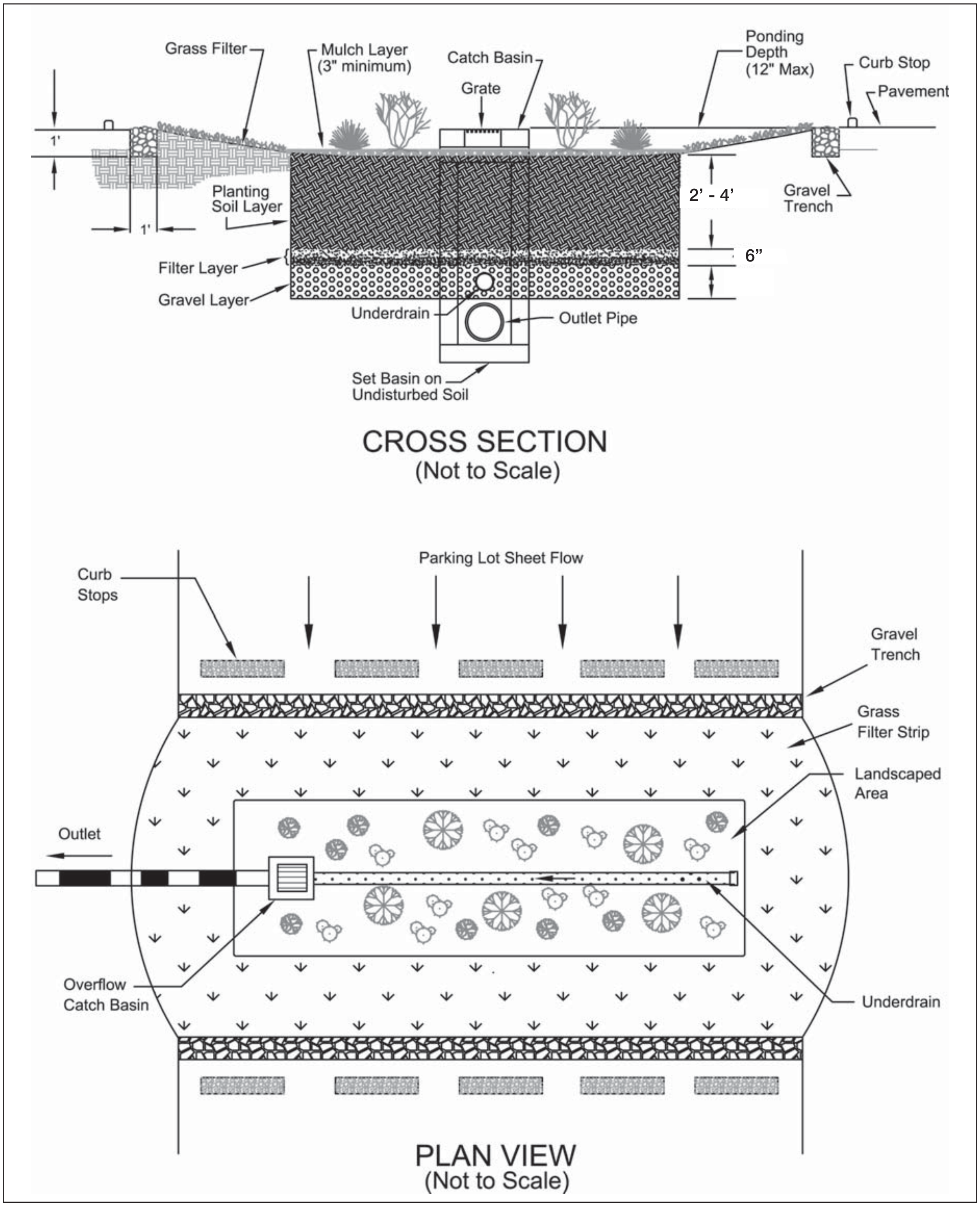
Specifications
for

Bioretention Areas



2.11 Pervious Pavement

Figure 2.11.1 Porous Concrete at Indian Run Park in Dublin, Ohio.

Description

Pervious pavement systems consist of a permeable pavement surface layer and one or more underlying aggregate layers designed to temporarily store stormwater. Most pervious pavement systems are designed to infiltrate stormwater into the underlying soil, reducing the volume of runoff leaving the site. Where the underlying soil will not permit full infiltration of runoff, outlets and/or underdrains are used to remove excess runoff and discharge it to an appropriate outlet[1].

Research has shown that pervious pavement can be a very effective component of a stormwater management system, mitigating many of the water quality and quantity impacts associated with runoff from impervious pavements. Pervious pavements reduce suspended solids, metals and petroleum hydrocarbons in runoff, and significantly reduce runoff volumes and peak flow rates.

Pervious pavements perform water quality functions by filtering suspended solids and hosting microbial organisms known to biodegrade pollutants. Depending upon the construction of the pavement, soil infiltration, transpiration (vegetated open celled grids), and increased soil adsorption may all contribute to reducing offsite runoff and associated adverse impacts. Additionally pervious pavements provide some moderating of water temperatures compared to traditional pavements.

1 Note that pervious pavements and their drainage strucures must be considered as part of the larger site and stormwater system when meeting local peak discharge requirements.

There are a variety of pervious pavement surfaces available in the commercial marketplace, including pervious concrete, porous asphalt, permeable interlocking concrete pavers, clay pavers, concrete grid pavers, and plastic grid pavers. While the design specifics vary for each product, pervious pavements have the same general structural components detailed in this practice.

There are several examples of pervious pavement installations that are still functioning well after 15 or 20 years (see e.g., Adams, 2003). If designed, constructed, and maintained according to the following guidelines, pervious pavements should have life spans comparable to traditional pavements.

Condition where practice applies and settings to avoid

Pervious pavement can be used in most settings where traditional pavements are used. It is especially well suited to parking lots, sidewalks, playgrounds and plazas. Pervious pavement can be used in driveways if the homeowner is aware of the stormwater management function and subsequent maintenance requirements of the pavement.

Areas of Heavy Traffic - Pervious pavement typically is not suitable for areas that experience high traffic loads or high vehicle weight traffic such as busy roadways or travel lanes in heavily used parking lots. However, pervious pavement is suited for parking lanes on roadways and in parking lots. When it is necessary to use traditional pavement for traffic lanes, runoff can be directed as sheet flow to pervious pavement areas.

Areas of Potential Groundwater Contamination – Pervious pavements should not be used in heavy industrial developments, areas with chemical storage, fueling stations or areas with significant risk of spills that might contaminate groundwater. Pervious pavements should not be used for sites located over contaminated soils without placing an impermeable liner between the pavement structure and soils.

Other Sites to Avoid

Unstable slope areas – pervious pavement should not be used in slip prone areas where concentrated infiltration may exacerbate slope instability

Steep slopes - areas with slopes steeper than 10 percent present design challenges that are difficult to overcome

Sediment sources - sites with sources of sediment (from vehicles, bare soils, spoil piles, sand storage, etc.) should be separated from pervious pavements with filter strips or other sediment removal practices.

Anticipated Performance

Pervious pavements are projected to perform well in reducing the annual load of suspended solids, metals and hydrocarbons in runoff, and significantly reduce runoff volumes and peak flow rates. Pervious pavements filter solids in the pavement layer and may completely remove them in the matrix of the sub-pavement layers depending upon the nature of the subgrade and designed drainage of the system. Though this varies with design; filtering, detention, adsorption processes all contribute to some degree in reducing pollutants in contributed flows and offsite runoff. Pervious pavements also buffer water temperatures. Increased infiltration into the subgrade soils contributes to the highest removal of pollutants from site runoff, although some pollutants such as soluble nutrients, chlorides or sodium raise concern for groundwater pollution.

Table 2.11.1 Anticipated performance of pervious pavements.

Category	Subcategory	Full WQv Infiltration	Partial Infiltration	No Infiltration
Runoff Water Quality	Suspended Solids*	>90%	80-90%	80%
	Phosphorus*	Medium	Medium	Medium
	Nitrogen/Nitrates*	Low	Low	Low
	Heavy Metals	High	High	High
	Bacteria	Not clear at this time. Other practices using media filtration do treat bacteria. Using a sand layer may enhance this.		
	Thermal	Pervious pavements with a reservoir storing the WQv or most of that volume are expected to provide good thermal attenuation, but this will vary based on the particular design (i.e. material, the storage volume, outlet configuration etc.)		
	Oil and Grease	High	High	High
	Poly Aromatic Hydrocarbon	Reduced compared to runoff from traditional ashalt		
	Chlorides & Sodium**	Not controlled.		
Runoff Volume Reduction		85-90%	%WQv-captured * 85%	
Recharge		High	Medium	Not at all.
Runoff Time of Concentration		Improved lag time, but varies with design.		
Peak Flow Attenuation		Significant peak flow attenuation, but varies with design.		

*** There would be an expected improvement with the addition of sand layers and/or vegetative systems.**
**** May be a significant groundwater concern depending upon winter application practices.**

Planning Considerations

Preliminary Site Evaluation - The overall site should be evaluated for potential pervious pavement/infiltration areas early in the design process, as effective pervious pavement design requires consideration of soils, grading, outlets, groundwater, and other site infrastructure.

Size of Project – Small projects such as walkways, or driveways with limited traffic may not have associated requirements for treating or storing stormwater. Therefore small scale projects may not need the depth of stone reservoir described in this practice. There are still numerous benefits to applying pervious pavements even with less stone subbase than this practice describes. For small scale practices where local or state regulations do not require treating the water quality volume, manufacturer recommendations should be consulted.

Soils - Pervious pavements may be used on any soil type, although soil conditions determine whether an underdrain is needed. Less permeable soils (most Hydrologic Soil Group C or D soils, some HSG B soils) usually require an underdrain, whereas soils with higher permeability (HSG A, and some HSG B soils) often do not. Estimates of soil permeability are available based on soil type, but designers should verify underlying soil permeability rates before proceeding with site and stormwater system design (see discussion below). Special measures may be needed when pervious pavement will overlay high shrink-swell soils in order to limit moisture or to stabilize these soils.

Subgrade Compaction - One of the major benefits of pervious pavement is runoff volume reduction from infiltration into underlying soils. Subgrade compaction severely limits the infiltration capacity of the underlying soil. For pervious pavement systems with an infiltration component, the subgrade should not be compacted according to traditional pavements. Structural integrity of pervious pavements is ensured through several mechanisms other than subgrade compaction (see discussion below). If the structural design of the pavement section requires subgrade compaction to achieve the required design strength or to minimize the possibility of pavement failure, then soil permeability should be measured based on the required subgrade design.

Separation Distances - Pervious pavements should not be located or used where their installation would: create a significant risk for basement seepage or flooding; interfere with public or private wells, septic or sewage disposal systems; or cause problematic groundwater issues. These issues should be evaluated and potential problems avoided by the designer.

Horizontal Separation Distances

- separation from buildings - pervious pavement systems should be installed at least 10' away from up-gradient building foundations and 100' from down-gradient foundations, unless an acceptable barrier is provided or the building foundation can adequately handle additional water;
- sanitary sewers - care should be taken to minimize infiltration of runoff into sanitary sewers and building laterals;
- septic systems - pervious pavement should be installed no closer than 100' from a septic system or leach bed; when this or any infiltration BMP is located up-gradient, appropriate perimeter drainage should be used to prevent flows from reaching the septic system;
- drinking water wells - pervious pavement should not be located within 25' of a private drinking water well or within the sanitary isolation radius of a public drinking water supply well. (The isolation radius ranges from 50 to 300 feet, and is based on the well's average daily pumpage; see the chart below.) If it is necessary to pave within the sanitary isolation radius, use of an impermeable bottom liner and an underdrain discharging beyond the isolation radius is recommended, especially if the pavement will support motorized vehicles.

Feature protected by setback	Setback Distance (feet)	
Building Foundations or basements	At least 10' downgradient or 100' upgradient of foundations	
Septic Systems	At least 100' separation	
Private Well	At least 25' (See OAC 3701-28-10)	
Public Well	50 – 300 ft minimum depending upon Average Daily Water Demand (based upon sanitary isolation distance found in OAC 3745-9-04)	
	Average Daily Pumpage (Q) (gal/day)	Sanitary Isolation Radius (feet)
	0-2500	50
	2501-10,000	Square root of Q
	10,001 – 50,000	50 + Q/200
	Over 50,000	300
Source Water Protection Area	See Ohio EPA Source Water Protection Area. Each area may have its own specific requirements.	

Table 2.11.2 Horizontal separation distances.

Vertical Separation Distances - Give special consideration to the following situations:

- Infiltrating pervious pavement systems with recharge layers located over soils with ground water tables that reach within 2 feet of the subgrade infiltration bed.
- Infiltrating pervious pavement systems with recharge layers located over impermeable bedrock within 2 feet of the subgrade infiltration bed.

These situations are likely to result in mounding of stormwater to the level of the infiltration bed for extended periods, especially during the spring. These systems may still help meet watershed management goals - for example, baseflow maintenance and temperature moderation during summer low-flow periods. However, a more thorough mapping and modeling of surface and subsurface hydrology is necessary to prevent unintended consequences. The pavement system configuration and drainage system should be modified to achieve stormwater management goals while minimizing unintended consequences.

Soil surveys can be used as rough guidance during initial planning and site layout to identify areas where shallow water tables or shallow bedrock may be a concern. However, in areas where these concerns are known, a professional geotechnical engineer and/or professional soil scientist should be contracted to take core samples to a depth of 6 ft below the proposed subgrade depth and report: depth to bedrock, any layering of the subgrade representing significant changes in texture or structure, the particle size distribution of the subgrade soil, the particle size distribution of any deeper layers, and depth to water table (ideally the water table will be checked between late March to early May when the water table is highest).

Groundwater Concerns – Pervious pavement, as with any infiltrating practice, requires the designer to consider the potential for adversely impacting groundwater. Elevated pollution sources or areas with high risk of toxic spills should not be directed to pervious pavement without appropriate pretreatment.. Examples include maintenance yards where salt storage or distribution takes place, airport areas where deicing occurs, fueling stations and composting facilities.

Development sites that include both relatively clean runoff (e.g., rooftop runoff) and dirtier runoff (e.g., from a maintenance yard or material storage area) should consider separate stormwater management systems appropriate to the specific runoff source. In such a scenario, rooftop runoff or runoff from office parking could be safely directed to an infiltrating BMP without pretreatment, whereas runoff from a maintenance yard should be treated in a separate facility designed to minimize potential negative impacts to groundwater. Such areas should be separated with physical barriers (fence, curb, etc.) to minimize tracking of pollutants into “clean” runoff areas.

Karst Terrain - Active karst regions are found in parts of Ohio (Hull, 1999; ODNR, 1999), and complicate development and stormwater system design. The use of permeable pavement or other infiltration BMPs in karst regions may promote the formation of sinkholes. In karst regions, a detailed geotechnical survey should be conducted to the satisfaction of the local approval authority. Permeable pavement designs in karst should exceed the minimum vertical separations recommended above and consider the use of an impermeable bottom liner and an underdrain. Additionally they should not receive runoff from other (external) impervious areas.

Freeze-Thaw - Water entrapped in the pavement course during freezing and thawing cycles will result in cracking, scaling and/or deterioration of the pavement (NRMCA, 2004). Therefore, the pavement structure and drainage system should be designed to ensure free drainage of the pavement surface and to prevent ponding into the pavement structure.

Frost Heave - Frost heave occurs when underground water accumulates in ice formations or ice "lenses", expanding and pushing the pavement structure upward resulting in uneven pavement (Leming et al., 2007) . Unlike their traditional counterparts, pervious pavements are specifically designed to introduce water below the pavement surface. Therefore, the pavement structure and drainage system should be appropriate for the subgrade soils (Leming et al., 2007; UNH, 2009).

One recommendation is to increase pavement thickness to accommodate the extra load carried by the surface course during spring thaw (Leming et al., 2007). This is reflected in some guidance for specific pavement surfaces (see e.g., ORMCA, 2009).

Frost heave is a serious concern for finer textured soils. Sands and coarser aggregates are much less susceptible to frost heave. One straightforward approach to minimize frost heave is to provide a base aggregate course thickness to minimize the formation of ice in the underlying subgrade. The University of New Hampshire Stormwater Center (UNH, 2009) recommends that the thickness of the pervious pavement structure (i.e., pavement plus sub-base thickness) be a minimum of 0.65 x design frost depth for the location. Local maximum frost penetration depth oftentimes can be provided by the local building authority. In the absence of locally available information, the following table can be used.

Located North of Latitude	Max. Frost Depth (inches)	Min. Recommended Thickness (0.65 x Max Frost Depth in inches)
38.3	24	16
38.7	26	17
39.0	28	18
39.3	30	20
39.7	32	21
40.0	34	22
40.3	36	24
40.7	38	25
41.0	40	26
41.3	42	27
41.7	44	29
42.0	46	30

Table 2.11.3 Frost depth and minimum recommended pavement system (pavement + sub-base) thickness by latitude (interpolated from Fig. 13 in Floyd, 1978; http://www.ngs.noaa.gov/PUBS_LIB/GeodeticBMs/#figure13)

Grading – The bottom of the infiltration bed should be level or nearly level. Sloping bed bottoms will lead to poor distribution and reduced infiltration. It is recommended pervious pavement slopes be less than 5% to optimize the ponding depth under the pavement surface. If pavement slopes cannot be reduced, infiltration beds may be placed along a slope by benching or terracing the subsurface infiltration beds to promote more uniform infiltration.

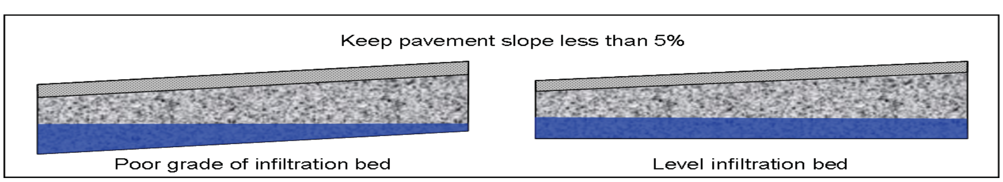


Figure 2.11.2 A level infiltration bed and limited pavement slope will maximize stormwater treatment and storage.

Figure 2.11.3 Terrace sloping areas to limit the pavement slope (photo credit: Brandon Andreson).

Runoff from External Areas - Drainage from traffic lanes or other impervious surfaces (e.g., sidewalks) can be directed to pervious pavement surface as sheet flow. The impervious area contributing runoff should be less than twice the area of pervious pavement receiving the runoff. Roof drains and leaders may connect directly to the subbase reservoir, but should be provided a means of trapping sediment prior to the subbase reservoir. Runoff from pervious areas (lawns or landscaping) or other sediment sources should not be directed onto pervious pavement.

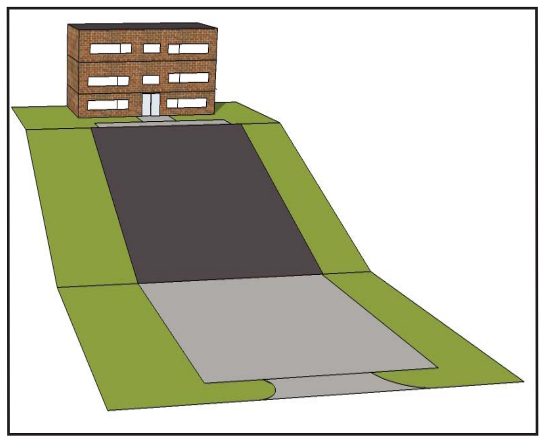


Figure 2.11.4 Calculate "run-on" from impervious areas, making sure it does not exceed twice the pervious pavement (infiltration bed) area.

Sites to Use or Consider Use of an Impermeable Liner

A liner should be used for pervious pavement systems for sites:

- all sites over contaminated (or potentially contaminated) soils
- sites with high pollution potential source areas
- sites with slip prone soils
- sites in source water protection areas

A liner may be considered for pervious pavement systems for sites with:

- subgrade soil infiltration rates less than 0.02 in/hr
- depth to bedrock or seasonal high water table less than 2 ft below subgrade infiltration bed
- karst geology

If the site requires a liner, the designer should consider whether a different BMP (e.g., bioretention, constructed wetland, wet swale) may be more appropriate.

Stormwater Detention - Sub-pavement infiltration beds are typically sized to manage the water quality volume and to convey stormwater without allowing ponding into the pavement itself.   These sub-pavement aggregate "reservoirs" also may be designed to mitigate the peak discharge of less-frequent, more intense storms (such as the critical storm or 100-yr event). Discharge control typically is provided by an outlet control structure. The specific design of these structures may vary, depending on factors such as rate and storage requirements.

Construction Sequencing - The pervious pavement system is most susceptible to failure during construction, and therefore it is important that the construction be undertaken in such a way as to prevent:

• Compaction of underlying soil

• Clogging the subgrade soil or geotextile with sediment and fines

• Tracking of sediment onto pavement

• Drainage of sediment laden waters onto pervious surface or into aggregate base

Pervious pavement will be prone to failure if it is not protected from sources of sediment. For this reason, insure that nearby areas or areas contributing runoff are completely stabilized prior to construction of the pervious pavement system. Sediment on the subgrade infiltration bed will greatly reduce the infiltration capacity of the final practice. Therefore special measures are needed to avoid this situation. Quick succession from excavation to placement of materials during dry weather is ideal for protecting the practice's long term functioning. Planned pavement areas that will be exposed for a period of time while other site construction occurs may be excavated within twelve (12) inches, but no closer than six (6) inches, of the final subgrade elevation. Following construction and site stabilization, sediment should be removed and final grades established when materials can be placed in a timely manner.

Maintenance - Pervious pavements have different maintenance requirements than traditional pavements, discussed in some detail below. The use of pervious pavement must be carefully considered in all areas where the pavement potentially could be seal coated or paved over due to lack of awareness by a new owner, such as individual home driveways. In those situations, a system that is not easily altered by the property owner may be more appropriate. Educational signage at pervious pavement installations may promote its prolonged use. Maintenance is critical to the long-term performance of pervious pavement, especially those activities that prevent clogging of the surface pavement and subsequent clogging of the subsurface layers by accumulated sediments and organic matter. The most important activities to protect the long term function of pervious pavement include periodic vacuum sweeping to remove accumulated sediments and organic materials, monitoring of the drainage functions of the pavement and maintenance/cleanup of landscaped areas contiguous to the parking area (CSN, 2010).

Cost Considerations - The primary added cost of a pervious pavement/infiltration system lies in the underlying aggregate bed, which is generally deeper than a conventional pavement subbase. However, this additional cost may be offset by a significant reduction in the number of inlets and pipes. Pervious pavement systems may eliminate or reduce the need (and associated costs, space, etc.) for surface detention basins. When all these factors are considered, pervious pavement with infiltration is increasingly competitive with traditional pavement for the pavement and associated stormwater management costs.

Types of Pervious Pavement

Porous Asphalt - Porous asphalt is very similar to standard bituminous asphalt except the fines have been removed to maintain interconnected void space. Research has led to improvements in porous asphalt through the use of additives and higher-grade binders. Porous asphalt is similar in appearance to standard asphalt and is suitable for use in any climate where standard asphalt is appropriate. Guidance specific to the design, installation and maintenance of porous asphalt is available from the National Asphalt Pavement Association (NAPA, 2008) and the University of New Hampshire Stormwater Center (UNHSC, 2009).

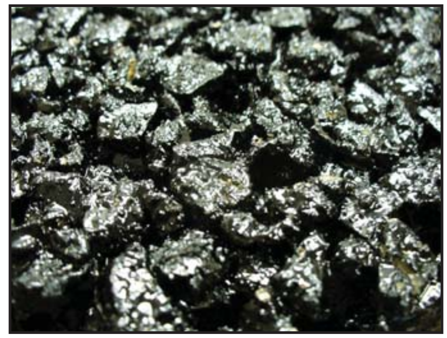


Figure 2.11.5 Porous Asphalt

Pervious Concrete - Pervious concrete is produced by reducing the fines in the mix to maintain interconnected void space for drainage. Pervious concrete has a coarser appearance than its conventional counterpart but may be colored similar to traditional decorative concrete. In northern climates such as Ohio, pervious concrete should always be underlain by a stone subbase designed for proper drainage and stormwater management, and should generally not be placed directly on a soil subbase. Special care must be taken during the placement of the pervious concrete to avoid overworking the surface and creating an impervious pavement. Guidance on the design, installation and maintenance of pervious concrete is available from the Ohio Ready Mix Concrete Association (ORMCA, 2009). ORMCA also offers installer training and certification for pervious concrete.

Figure 2.11.6 Pervious Concrete

Block or Brick Pavement - A number of concrete or clay paver products are available, providing either a traditional brick pavement look or more complex designs and configurations. Block or brick pavements maintain drainage through gaps between the pavers filled with small, uniformly-graded gravel. The pavers are bedded on a stone or sand layer that provides uniform support and drainage. Pavers are especially well suited for plazas, patios, small parking areas, parking stalls in larger lots, and streets.

Pervious interlocking concrete pavement (PICP) are one commonly used product that consist of 3 1/8" thick concrete units or pavers with various shapes, patterns, and colors. The size and complexity of the project determines whether PICP may be placed by machine or by hand. Guidance for design, installation and maintenance of concrete pavers is available from the manufacturer and the Interlocking Concrete Pavement Institute (ICPI, 1995).

Figure 2.11.7 Pervious Interlocking Concrete Pavement

Reinforced Turf and Gravel Filled Grids - Grid-type pervious pavements consist of open-celled concrete or plastic structural units filled with small, uniformly-graded gravel or turf that allows infiltration through the pavement surface. The structural units are underlain by a stone and/or sand drainage system for stormwater management. Reinforced turf applications are excellent for fire access roads, overflow parking, occasional use parking (such as at religious facilities and athletic facilities). Reinforced turf is also an excellent application to reduce the required standard pavement width of paths and driveways that must occasionally provide for emergency vehicle access.

Figure 2.11.8 Vegetatated Grid System utilitized for fire access.

Figure 2.11.9 Vegetated Grid System with established turf grass.

Design Criteria - General/Introduction

Pervious pavements typically will be designed to address two types of design criteria:

- Minimum specifications should be met to ensure the long-term structural performance appropriate to the specific use of the pavement (pavement type, location, type of traffic, traffic load, etc.). The pavement should meet all design, construction and maintenance requirements of the local approval authority.
- Secondly, pervious pavement typically will be part of the stormwater management infrastructure of the development site. Therefore, meeting specific design criteria should allow the pervious pavement system to receive credit toward meeting water quality treatment performance requirements of the NPDES Construction General Permit (OEPA, 2008) and/or receive appropriate credit toward meeting local peak discharge requirements.

Design Criteria - Stormwater Requirements

The Ohio DNR and Ohio EPA mandate is to ensure post-construction stormwater performance over the long-term. This means the pervious pavement system must show equivalent WQ performance to the structural BMPs listed in Table 2 of the NPDES Construction General Permit (Ohio EPA, 2008), or be part of a larger stormwater system that collectively meets those requirements. Pervious pavement can be used to meet the WQv requirement for either new development or re-development.

Full infiltration of WQv - Pervious pavement, without prior OEPA approval, may be used to meet the WQv requirements of the Construction General Permit (CGP) as long as the practices designed to fully infiltrate the WQv and follows the design, construction and maintenance protocols outlined in this section.

No infiltration - If the site is not suitable for deep infiltration (e.g., lined system or compacted subgrade), pervious pavement may be considered for WQv on a case-by-case basis with prior approval from OEPA and the local MS4. This scenario will require an appropriately designed outlet control to release runoff over a 24 hour period; however, no additional sediment storage volume (=0.2*WQv) is required. The volume of runoff detained shall drain over 24 hours, releasing no more than one half the volume in the first eight hours. Until further notice, monitoring of system function/performance is likely to be required.

Partial infiltration of WQv - If the site is capable of partially infiltrating the WQv, the volume infiltrated may be subtracted from the WQv when determining detention requirements. As for the no infiltration scenario, an appropriately designed outlet will be needed to release runoff over 24 hours, releasing no more than one half the volume in the first eight hours.. This scenario requires prior approval from OEPA and the local MS4.

Redevelopment Projects - For redevelopment projects, the area of pervious pavement receives a 1:1 credit toward the 20% reduction in impervious area requirement of the CGP. All areas draining to the pervious pavement receive credit toward the impervious area reduction as long as the storage layer is designed to hold and either infiltrate (within 48 hours) or release (with a drain time of 24 hours, releasing no more than half the WQv in the first 8 hours) the water quality volume AND the pervious pavement system meets all other requirements outlined in this guidance.

Inspection and Maintenance - Pervious pavement must be inspected and cleaned regularly to maintain the hydrologic performance of the pavement system. Therefore, Ohio EPA will consider pervious pavement as meeting the requirements of the CGP only if the property owner has a maintenance agreement approved by the local MS4 that includes the minimum practices outlined under the section titled “Maintenance” below.

Water Quality Calculations -

Calculate the **total water quality volume** (WQv) using the following equation:

$$WQv\ (ac\text{-}ft) = C*P*A \qquad \text{(Equation 1)}$$

Where: C = volumetric runoff coefficient
P = 0.75” rainfall
A = drainage area (acres)
For the pervious pavement surface, C = 0.89.

For other contributing drainage area, determine C according to guidance in the NPDES Construction General Permit (Ohio EPA, 2008). Either look up the C value in Table 1 of the CGP, or use the following equation:

$$C = 0.858i^3 - 0.78i^2 + 0.774i + 0.04 \qquad \text{(Equation 2)}$$

Where: i = watershed imperviousness ratio, the percent imperviousness divided by 100

If the additional contributing drainage area is entirely impervious surfaces (traditional pavements and/or roofs), i = 1 and C = 0.89.

No additional storage is required for sediment accumulation.

Converting Storage Volume to Storage Depth - The sub-pavement volume available for temporary storage of stormwater will typically be filled with aggregate (washed, uniformly-graded stone or gravel). The volume occupied by the aggregate itself is unavailable for water storage. The remaining volume of voids is available for storage of water:

$$V_T = V_S + V_V \qquad \text{(Equation 3)}$$

Where: V_T = Total Volume
V_S = Solids Volume
V_V = Voids Volume

A more common way to communicate about the volume available for water storage is the aggregate porosity, φ, the ratio of void-space volume to the total volume:

$$\varphi_{aggregate} = V_V / V_T$$

Aggregate porosity can range from 0.30 to 0.40 (Ferguson, 2005). However, some percentage of the voids will be unavailable for additional stormwater storage because of previous wetting and entrapped air resulting in a lower usable or effective porosity. We recommend using an aggregate porosity of φaggregate = 0.30 in the following calculations[2][3].

The aggregate thickness required to meet the WQv objective can be calculated:

$$D_{agg}\text{-}WQv = WQv/(A_{reservoir} * \varphi_{aggregate})$$

Where: D_{agg}-WQv = required aggregate thickness (L)
WQv = water quality volume (L^3)
$A_{reservoir}$ = basal area of aggregate reservoir (L^2)
$\varphi_{aggregate}$ = aggregate porosity

2 Note that the proosity of the pavement itself typically is substantially lower than the aggregate base; when needed for calculations, porosities for the pavement should be taken from guidance provided by the specific industry association.

3 A number of underground storage chambers have been developed and designed to provide both sturctural support for pavements and temporary stormwater storage. Because the void space within the chambers approaches 100%, these chambers may provide a cost-effective alternative to a sub-pavement reservoir consisting entirely of aggregate. Guidance for both the chambers and the industry association for the desired pavement should be consulted to ensure sturctural performance.

Drawdown Calculation - Ideally, the water quality volume will be drained within 48 hours in preparation for the next runoff event. The approach to determine drawdown characteristics is different depending on whether the pervious pavement is an infiltrating or non-infiltrating system.

The entire area under both pervious (e.g., parking lanes or pull-in parking) and traditional pavement (e.g., traffic lanes) may be used as infiltration or storage area as long as the WQv/sub-base gravel layer is fully interconnected and the soil infiltration capacity is adequate throughout the area. A minimum of 33% of the infiltration bed should be covered with pervious pavement.

For non-infiltrating systems, the drawdown calculation should follow the procedure used for surface detention basins with the depth and head adjusted for the porosity of the aggregate. For WQv detention under pervious pavement, a 24 hour drawdown time is recommended, with no more than ½ of the water quality volume draining from the facility in the first 8 hours. The drawdown control device should have a minimum orifice diameter of 1".

For infiltrating systems, the WQv should be infiltrated into the subgrade soil within 48 hours. The design infiltration rate of the subgrade soil will be based on field measurements at the appropriate depth, and be verified during construction (see section on measurement and verification of subgrade infiltration rate). The infiltration rate shall be based on the final, after-compaction subgrade properties, if compaction is required[4].

There are a number of factors - including soil compaction, surface smearing, aggregate "masking", sedimentation, and air entrapment - that typically mean the actual infiltration rate under real-world, post-construction conditions will be substantially lower than the measured infiltration rate. To increase the likelihood of achieving design performance over the long-term, it is recommended that an infiltration rate equal to one-half the measured infiltration rate of the subgrade be used for the design:

$$f_{design} = 0.5 * f_{measured}$$

Where: f_{design} = design subgrade infiltraion rate (L/T)

$f_{measured}$ = field measured subgrade infiltration rate (L/T)

The following table presents estimates of design infiltration rate that can be used for initial planning considerations until field measurements can be collected[5].

Soil Texture of Subgrade Soil	Clay Content (%)	Clay + Silt Content (%)	Preliminary f_{design} (in/hr)	Soil Texture of Subgrade Soil	Clay Content (%)	Clay + Silt Content (%)	Preliminary f_{design} (in/hr)
Sand	< 8	< 15	3.0	Sandy Clay Loam	20 - 35	<55	0.05
Loamy Sand	< 15	< 30	2.0	Clay Loam	27 - 40	54 - 80	0.02
Sandy Loam	< 20	< 60	0.9	Silty Clay Loam	27 - 40	>80	0.02
Loam[5]	7 - 27	48 - 80	0.2	Silty Clay	40 - 60	>80	0.02
Silt Loam[5]	< 27	48 - 100	0.1	Sandy Clay	35 -55	<55	<0.01
Silt[5]	<12	80 - 92	0.1	Clay	> 40	>55	<0.01

Table 2.11.4 Estimated infiltration rate based on soil texture.

4 If the subgrade will be compacted to meet structural design requirements of the pavement section, the design infiltration rate of the subgrade soil shall be based on measurement of the infiltration rate of the subgrade soil subjected to the compaction requirements.

5 For silt, silt loam and loam subgrade textures, check for the presence of a fragipan, which can severely limit permeability.

For infiltrating systems, the drawdown calculation shall be determined using the following equation. The infiltration area A_{inf} shall be the bottom area of the infiltration bed.

$$T_d = WQv / (f)(A_{inf})(\varphi_{aggregate})$$

Where

T_d = drawdown time (T)
WQv = water quality volume (L^3)
f = infiltration rate of subgrade soil (L/T)
A_{inf} = area of infiltration bed (L^2)
$\varphi_{aggregate}$ = porosity of aggregate base

WQv Sample Problem

A site in Columbus proposes to install 1 acre of pervious pavement that will also receive sheet flow from 2 acres of traditional asphalt. The subgrade infiltration area is equal to the area of the pervious pavement. The measured subsurface infiltration rate (fmeasured) of the native soil is 0.5 in/hr. The aggregate base is composed of No. 57 aggregate. Calculate the WQv, the depth of the WQv, the porosity adjusted WQv depth, and the time necessary for the WQv to drain into the native soil.

Calculate the WQv:

WQv = C*P*A

i = 100% impervious = 1.0

C = 0.89

P = 0.75 inches

A = 3 acres

WQv = (0.89)(0.75 in)(3 ac) = 2.0 ac-in = 0.17 ac-ft = 7300 ft^3

Calculate the WQv "depth":

DWQv = WQv/A_{inf} = 2.0 ac-in/1.0 ac = 2.0 inches

Calculate the porosity adjusted WQv depth:

$\varphi_{aggregate}$ = 0.30

D_{agg}-WQv = WQv /(A_{inf})($\varphi_{aggregate}$) = DWQv /($\varphi_{aggregate}$) = 2.0 in/0.30 = 6.7 inches

Calculate the WQv drain time:

$f_{design} = 0.5\ f_{measured}$ = 0.5 (0.5 in/hr) = 0.25 in/hr

T_d = WQv / (A_{inf})(f_{design}) = 2.0 ac-in/(1.0 ac * 0.25 in/hr) = 8 hr

T_d = 8 hr < 48 hr

Water Quantity (incl. Peak Discharge) Credits - The peak rate of runoff from a site is radically altered by development. The addition of impervious surfaces, the hardening of pervious areas, and the improved hydraulic efficiency of the drainage network all contribute to greatly increased flow peaks, as well as extended periods of elevated discharge. Pervious pavements have been shown to considerably reduce flow peaks, when compared with traditional pavements, through several mechanisms including subgrade infiltration (also called exfiltration), temporary storage and increased flow path resistance.

Pervious pavement can be encouraged by appropriately crediting the stormwater management benefits provided. The ways that pervious pavement potentially can receive credit include:

- infiltration or extended detention of the WQv (described above)
- stormwater utility credit or fee reduction
- critical storm adjustment
- peak discharge attenuation

The ways that pervious pavement may be used to fulfill the WQv requirement are discussed in the previous section. The other three quantity "credits" are discussed here.

Stormwater Utility Credit - [Note: All credits are at the discretion of the local stormwater management authority.] All contributing drainage area for which the pervious pavement system fully infiltrates the WQv should receive full credit for runoff volume reduction and water quality purposes, and partial to full credit for peak flow reduction. Pervious pavement systems with partial or no infiltration should be considered for a partial credit because of the combination of water quality benefits, runoff volume reduction, and flow peak reduction.

Critical Storm Adjustment - The State of Ohio does not regulate stormwater discharges for large, infrequent rainfall events (e.g., 1-year to 100-year events). However, controlling discharge for these events is an important consideration toward protecting public safety and minimizing damage to property and infrastructure. Many Ohio communities have peak discharge or "flood control" regulations aimed at reducing the impacts of large events. Many of those communities have adopted the Critical Storm criteria for peak discharge control (ODNR, 1980). The following recommendations are designed to encourage consideration of pervious pavement while still protecting the public interest.

For pervious pavement systems, the CN for Critical Storm determination should be based on the abstraction potential, which is a function of infiltration capacity of the underlying soil and the elevation at which underdrains are placed above subgrade. Until more definitive research is developed by NRCS or another research entity, it is recommended that the Critical Storm CN for the pervious pavement system be based on TR-55 guidance (USDA, 1986) for "newly graded areas" or "open space in poor condition" based on the hydrologic soil group (HSG) of the in-situ soil and the measured subgrade infiltration rate upon completion of excavation of the underground reservoir.

Soil HSG (in/hr)	Measured Infiltration Rate	CN
A	> 1.0	68
B	> 0.02	79
C	> 0.05	86
D	> 0.02	89

Table 2.11.5 Recommended Critical Storm CN for A_{inf} for No Underdrains or Underdrains Placed D_{agg}-WQv or Higher above Subgrade.

Soil HSG (in/hr)	CN
A	77
B	86
C	91
D	94

Table 2.11.6 Recommended Critical Storm CN for A_{inf} for Underdrains Placed Directly on Subgrade.

Modeling Stormwater Detention and Peak Discharge Attenuation - The aggregate subbase "reservoir" can be used as a detention basin to temporarily store stormwater. Outfitted with an appropriate outlet, the aggregate reservoir may be able to meet local peak discharge requirements for the area that drains to the pervious pavement system. Otherwise, the aggregate reservoir and outlet become part of the overall drainage network that needs to be properly "routed" to determine inflow to an end-of-pipe facility.

The following guidelines will help ensure the pervious pavement system achieves long-term structural and stormwater management goals:

- Peak discharge requirements are set by local regulations. All stormwater systems that incorporate pervious pavement require review and approval from the local stormwater authority. Preliminary approach, plans and calculations should be discussed as early as possible with the plan reviewer to facilitate communication and avoid delays in review and approval.
- The available storage volume is equal to area*depth*effective porosity of the aggregate layer(s).
- though porosities for washed, uniformly-graded aggregate may approach 0.4, some percentage of the voids will be unavailable for storage because of previous wetting and entrapped air resulting in a lower usable or effective porosity; for consideration of intense design events such as a NRCS type II distribution, use of a conservative effective porosity of 0.3 for clean, uniformly-graded aggregate is merited.
- the porosity of the pavement course typically will be substantially lower than the aggregate base; when needed for calculations/routing, porosities for the pavement should be taken from guidance provided by the specific industry association.
- For infiltrating systems, the modeler should assign a steady discharge (often termed exfiltration rate) equal to the final (or minimum) infiltration rate.
- The aggregate reservoir should be designed to prevent the (routed) 10-yr, 24-hr design event from entering the pavement course.
- The site design should include a secondary, surface drainage network that will pass the 100-yr, 24 hr event without damage to property assuming failure of the pervious pavement system. The model should show flow paths and elevations for the 100-yr, 24-hr design event with the pervious pavement treated as impervious.

Subgrade Infiltration Capacity - The hydrologic performance of infiltrating pervious pavement systems requires special attention to the subgrade soil (i.e., soil at the bottom of the aggregate reservoir) and the infiltration bed surface throughout planning, design and construction. The following guidelines will help ensure the pervious pavement system achieves long-term stormwater management goals:

- The bottom surface area of the infiltration bed should not be less than the surface area of the pervious pavement. The designer should consider increasing the infiltration bed surface area by extending the infiltration bed under adjacent traditional pavement. Such an expansion of the infiltration bed may be necessary to achieve the required drawdown time for the WQv.
- The bottom surface area of the infiltration bed should be at least 33% of the sum of the area of the pervious pavement surface plus all contributing impervious surfaces (parking lot, roads, driveways, sidewalks, roofs, etc.), that is Ainf > 0.33*(Aperv-pave + Aimpervious).
- The bottom of the infiltration bed should be level or nearly level. Sloping bed bottoms will lead to poor distribution and reduced infiltration.
- For infiltrating systems, the subgrade should not be compacted as it would be for traditional pavements. If the structural design of the pavement section requires subgrade compaction to achieve a required design strength, then subgrade infiltration should be measured based on the required subgrade design.
- The design infiltration rate of the subgrade soil should be based on field measurements at the appropriate depth and verified during construction (see section on measurement and verification of subgrade infiltration rate).

Design Criteria - Pavement Structure Design

Structural Design – The designer shall refer to the appropriate industry association or manufacturer's specifications for structural design of the pervious pavement system.

Table 2.11.7 Reference appropriate specifications for structural design.

Pavement Type	Guidance	Website
Porous Asphalt	Porous Asphalt Pavements for Stormwater Management: Design, Construction and Maintenance Guide. Info Series 131, Revised November, 2008. National Asphalt Pavement Association, Lanham, MD.	www.asphaltpavement.org
Pervious Concrete	Specifier's guide for Pervious Concrete Pavement with Detention. Revised October, 2009. Ohio Ready Mixed Concrete Association, Columbus, OH.	http://www.ohioconcrete.org
Concrete Pavers	Structural Design of Interlocking Concrete Pavement for Roads and Parking Lots. ICPI Tech Spec Number 8. Interlocking Concrete Pavement Institute, Washington, DC.	http://www.icpi.org
Grid Pavements	Concrete Grid Pavements. ICPI Tech Spec Number 8. Interlocking Concrete Pavement Institute, Washington, DC.	http://www.icpi.org
Vegetated Grid Pavements	See various manufacturer specifications	

Infiltrating Systems:

Pavement & bedding material - see industry association guidance.

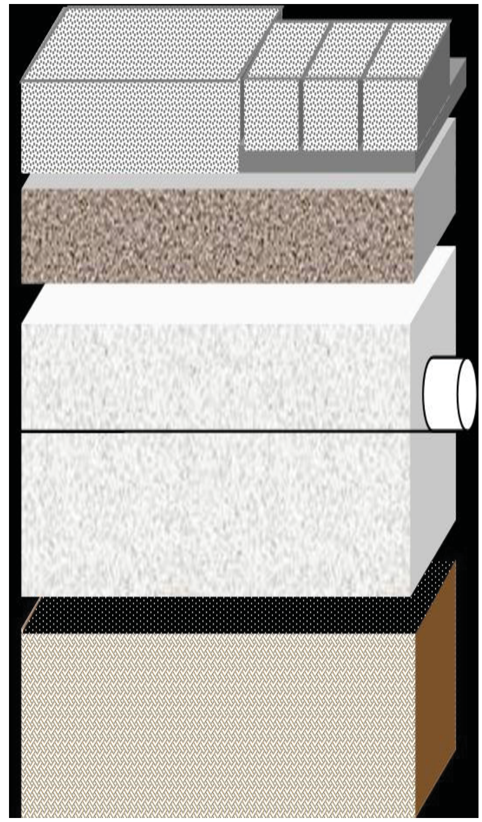
Filter/choker course - minimum 2” of AASHTO #57 if larger aggregate is used for reservoir course or AASHTO #7, #8 or #9 if the reservoir course uses #57.

Underdrains - 4”-6” dia. PVC placed at top of recharge layer.

Recharge course - sized to infiltrate the WQv from the contributing drainage area (minimum 3” depth). Typically AASHTO #57 or larger.

Permeable geotextile fabric or sand layer equivalent

Subgrade - uncompacted subgrade



Closed Systems:

Pavement & bedding material - see industry association guidance.

Filter/choker course - minimum 2” of AASHTO #57 if larger aggregate is used for reservoir course or AASHTO #7, #8 or #9 if the reservoir course uses #57.

Reservoir course - clean, uniformly-graded coarse aggregate, typically #57, #4, #3 or #2.

Underdrains - 4”-6” dia. PVC placed placed on subgrade.

Impermeable liner (if necessary)

Compacted subgrade graded with positive slope toward outlet (minimum slope - 1%?)

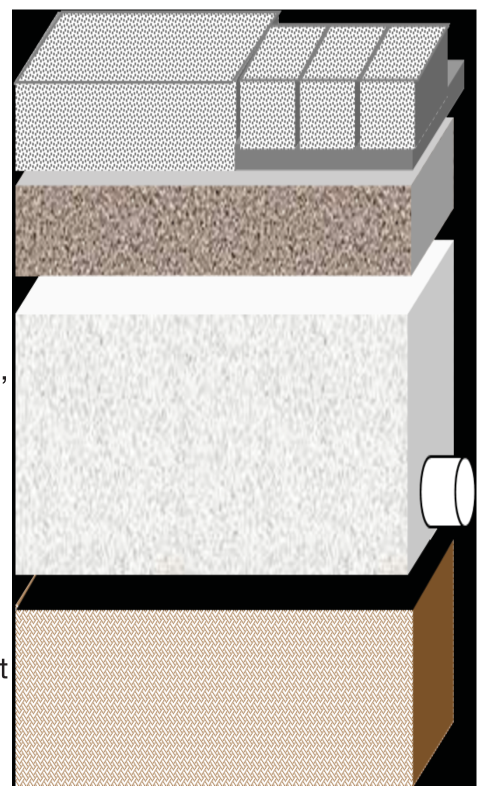


Figure 2.11.10 Types of materials used in infiltrating and closed pervious pavement systems.

Subgrade Preparation - The subgrade shall be designed to carry the desired traffic load. Check the appropriate industry association or manufacturer's specifications for compaction requirements. Design infiltration rates must be adjusted to account for intended and unintended subgrade compaction.

Subgrade Soil/Aggregate Base Interface - For open (infiltrating) systems on fine-textured soils a geotextile should be placed between the native soil and the aggregate base[6]. The geotextile limits the migration of fines, limits the settling of aggregate into the underlying soil, and helps to distribute surface loads.

For infiltrating systems, given the soil characteristics of the native soil, alternative materials such as a layer of clean sand may be placed in lieu of a geotextile on top of the native soil layer to provide adequate separation between the native soil and aggregate base in an open system (UNHSC. 2009).

For closed systems, an impermeable liner shall be placed between the native soil and the aggregate base using standard measures to prevent puncture of the geomembrane (e.g., smooth subgrade, sand bedding, geotextile). Prevent lateral flow by bringing the impermeable liner to the surface or by securing the liner to a cut-off or perimeter wall making sure that the outlet pipe and any other penetrations of the liner are adequately sealed. An impermeable liner should be used for pervious pavement systems for:

- all sites over contaminated (or potentially contaminated) soils
- sites with high pollution potential source areas
- sites with slip prone soils
- sites in source water protection areas

A closed system may also be used to prevent saturation of the underlying soil for structural reasons; consult a geotechnical engineering or pavement design engineer to determine whether a closed system is required based on soil conditions.

Perimeter Barrier: Some paving materials will be prone to lateral movement unless secured against a perimeter barrier. This may be a cut stone or concrete barrier or a manufactured edge restraint. Concrete barriers at the surface grade or as a raised curb can also serve as a way to secure the impermeable liner in non-infiltrating systems to prevent lateral flow between cells in a sloping situation. Where open graded subbase material will be place against conventional road base material or soils, some type of barrier is probably needed to prevent migration of fines into the permeable pavement subbase and movement of water into the conventional road base.

Aggregate Bed - The underlying aggregate bed is typically 8-36 inches deep and is a function of structural requirements, stormwater storage requirements, frost depth considerations, site grading, and anticipated loading. Several sizes of aggregate may be required for pavement bedding, choker courses, or stormwater storage. It is critical the aggregate be uniformly graded, clean washed, and contain a significant void content. A range of aggregate sizes has been used successfully in pervious pavement projects. Choice of aggregate(s) will depend on structural requirements, local availability, and cost. Check the appropriate industry association or manufacturer's specifications for specific aggregate requirements.

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6 UNHSC, 2009. UNHSC Design Specifications for Porous Asphalt Pavement and Infiltration Beds. Revised October, 2009. University of New Hampshire Stormwater Center, Durham, NH. http://www.unh.edu/erg/cstev/pubs_specs_info.htm.

Underdrains and observation well - Most pervious pavement systems should be designed with an underdrain system to efficiently drain the system during larger events. To avoid damage to the pavement layer, water within the subsurface stone storage bed should only rise to the level of the pavement surface in extremely rare events based on the risk tolerance of the engineer, owner or MS4 (we recommend a minimum of the 10-yr, 24-hr event). Underdrains should be installed with a minimum slope of 1% and capped at dead ends of drains. For pervious pavement areas of at least 10,000 square feet, at least one observation/cleanout standpipe should be installed near the center of the pavement and shall consist of rigid 4 to 6 inch non-perforated PVC pipe. This should be capped flush with or just below the top of pavement elevation and fitted with a screw or flange type cover. Portions of the underdrain system within 1 foot of the outlet structure should be solid and not perforated.

Figure 2.11.11 Commonly used stone for choker and reservoir layers (not to scale).

Construction

Any non-traditional stormwater practice presents challenges during the construction phase that require extra attention to plan detail (both for the design engineer and the contractor) and benefit from construction oversight by the design engineer or others with intimate knowledge of system design and function. Infiltrating pervious pavement systems increase complexity by striving to maintain infiltration capacity while ensuring structural integrity. For these systems, the design engineer should provide additional detail or requirements that protect or assure design infiltration capacity, and this capacity should be confirmed with field measurements during construction.

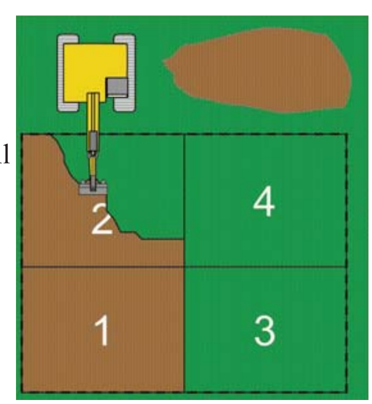
Acceptable Conditions for Initiating Construction - Construction of the pervious pavement shall begin only after all the contributing drainage area has been stabilized with vegetation or the planned cover in order to prevent contamination with sediments. Do not construct the pervious pavement practice in rain or snow. Construction of any infiltration BMP should be completed during a window of dry weather - excess compaction or smearing of the subgrade will ensure failure of the stormwater functions of the practice and threaten non-compliance with local or state requirements.

Erosion, Sediment and Runoff Controls - Keeping sediment out of this practice is critical. Rigorous installation and maintenance of erosion, sediment and runoff control measures should be provided to divert runoff and to prevent sediment deposition on the pavement surface, the subgrade or within the stone bed. A non-woven geotextile may be folded over the edge of the pavement to reduce the likelihood of sediment deposition. Any construction materials that are contaminated by sediments must be removed and replaced with clean materials (CSN, 2010). Surface sediment should be removed as soon as possible using a vacuum sweeper.

Clearing and Excavation - Clear and excavate the area for pavement and base courses in a manner that maintains the infiltrative capacity to the greatest extent possible (Brown, 2010). First insure plans detail staging of work in order to maintain the infiltrative capacity of the subgrade soils. Compaction of the subgrade soils will be increased by working in wet conditions, allowing construction equipment to work or travel across the area and by smearing the final soil surfaces during excavation. Final grade of the bed should be level for infiltrating systems, while closed or lined systems should have positive drainage to the outlet. To protect and maintain subgrade infiltrative capacity (adapted from Brown, 2010):

- Do not all allow excavation in wet conditions or if wet weather is forecasted for the construction period or before the area can be filled. Excavate in dry soil moisture conditions and avoiding excavating immediately after storms without a sufficient drying period.
- Do not allow equipment or haul routes to cross the planned pavement area, especially once excavation has begun.
- Station and operate excavating equipment from outside the planned pavement area or from unexcavated portions of the area using an excavation staging plan (see figure 2.11.12).
- Leaving 6 to 12 inches of undisturbed soil above the subgrade elevation if geotextile and base material placement will be delayed.
- Dig the final 9-12 inches by using the teeth of the excavator bucket to loosen soil so as not to smear the sub grade soil surface. Grading of the bottom (subgrade) surface of the practice with construction equipment should be avoided. Final grading or smoothing of the bottom should be done by hand.
- Avoid allowing water to pond in bottom of cuts.

Figure 2.11.12 Stage excavation in order to avoid compaction.



- Areas that have been allowed to trap sediment must have sediment removed and be allowed to dry before final excavation down to the subgrade elevation. Any accumulation of sediments on the finished subgrade should be removed with light equipment and the subgrade surface lightly scarified with hand tools. *Very important note: limit breaking natural soil structure (especially for clayey-silty soils) or risk adversely impacting the infiltrative capacity of the subgrade.
- Finally, before placing geotextile and base aggregate, the final subgrade infiltration rate must be measured for infiltrating systems and reported to the local stormwater authority.

Place geotextile or planned filter material on the uncompacted subgrade and place geotextile up and over the sides of the excavated area. Place geotextiles so that there is a minimum of 16 inches of overlap between subsequent rolls of fabric (see manufacturers recommendation) and a minimum of four feet of material beyond the sides of the excavation. Secure geotextile so that it will not move or wrinkle as aggregate is placed. Some designers may use an alternative filter material such as sand and/or pea gravel between the base aggregate (reservoir layer) and the subgrade soils instead of geotextile (see e.g., UNHSC, 2009). Non-infiltrating designs may compact the subgrade and replace the geotextile with a suitable impermeable lining. Excess fabric (beyond the excavation) should not be trimmed until there is no possibility of sediment entering the pavement area.

Place reservoir course of aggregate and underdrain system. For infiltrating systems, plans will dictate the depth of aggregate to be placed beneath the underdrain system, although this generally exceeds 3 inches. Underdrains should be installed with a minimum slope of 1%. Dead ends of pipe underdrains shall be closed with a suitable cap placed over the end and held firmly in place. For pervious pavement areas of at least 10,000 square feet, at least one observation/cleanout standpipe shall be installed near the center of the pavement and shall consist of rigid 4 to 6 inch non-perforated pvc pipe. This should be capped flush with or below the top of pavement elevation and fitted with a screw or flange type cover. Portions of the underdrain system within 1 foot of the outlet structure should be solid and not perforated.

Moisten and spread 4-12 inch lifts of the washed stone aggregate comprising the reservoir layer. Place and spread lifts of stone without driving on the subgrade and being careful not to damage drainpipes, connections or observation wells. Place at least 4 inches of additional aggregate above the underdrain. The aggregate layer should be lightly compacted, although industry references vary on the degree and number of passes with a roller. The Interlocking Concrete Pavement Institute (ICPI, 2007; LID,) specifies making 2 passes with a roller in vibratory mode and at least 2 passes in static mode until there is no movement of the stone, while the National Asphalt Pavement Association recommends compacting each lift with a light roller or vibratory plate compactor. Do not crush the aggregate with the roller.

Install filter/choker layer (and bedding layer if used). This course transitions from a larger aggregate size of the subbase to a size that will fill large voids and provide a smooth surface for the pavement layer. Its use depends upon the size of the aggregate course below. For pervious concrete and porous asphalt, AASHTO No. 57 may be used for the reservoir layer and in the layer transitioning to pavement. For interlocking pavers, a smaller size aggregate will be used as a filter layer and also as a bedding layer. These layers should be spread, leveled and compacted to their designed thicknesses.

Install paving materials. Install the planned paving materials in accordance with manufacturer or industry specifications for the particular type of pavement, whether pervious concrete, porous asphalt (Hansen, 2008; Jackson, 2007), interlocking pavers or grid pavers.

Maintenance

Pervious pavements require maintenance to provide stormwater benefits over a long time period. Because pervious pavements convey water through the pavement and also effectively trap fine materials, the majority of maintenance efforts will be to keep the system permeable (unclogged) and to manage pollutants such as salts that might effect groundwater. Therefore regular inspection will evaluate whether the surface and the bed of the pavement are functioning as intended. In other words, water should continue to move through the pavement, not pond into the pavement layer, and drain from the reservoir layer in sufficient time. Maintenance of the pavement will remove fine materials as they collect in the surface and prevent winter deicing materials from being overused or clogging the system.

Effective management includes educating the property owner, landscapers, maintenance staff, snow removal personnel and general users. In this regard, an operation and maintenance plan, signage, maintenance agreements, and contracts will serve as important points of reference for these audiences. Each document should reflect the appropriate actions to take and those to avoid for the appropriate audience. For example, landscaping personnel that work adjacent to the pavement area should be required to keep landscaping materials, such as soil, mulch or plants off the pavement and to use adequate sediment control and/or stabilization for bare areas. Snow removal, pavement repair and similar contracts should include notes regarding appropriate and inappropriate actions regarding the pervious pavement area. Because pervious pavements will be maintained and managed differently than traditional pavements, signage at pervious pavement installations is recommended. This will promote its prolonged use and prevent conventional pavement management from damaging the system. An example of this includes preventing seal coating of porous asphalt or allowing snow to be stockpiled on a pervious pavement.

Figure 2.11.13 Examples of signage that might be used to protect pervious pavements.

An operation and maintenance plan should be prepared by the designer and provided to the owner and the stormwater authority as well as the property manager and maintenance personnel. An operation and maintenance plan for pervious pavement should detail specific actions that must be performed and their timing and/or frequency. It also describes potential damaging actions and measures to take to prevent damage to the pervious pavement. The operation and maintenance plan should also provide detailed information regarding the observation well and the depth or elevations of the underdrain system and outlet, so that the water levels under the pavement can be monitored and compared to the designed function of the system. The operation and maintenance plan should provide the normal drain time (hours) of the pavement.

Three main strategies dominate pervious pavement operation and maintenance:

Prevent clogging of the pavement and regularly remove accumulated fines. Vacuum sweeping is necessary to remove grit, leaves and other debris collecting at the pavement surface. This should be done two to four times a year. Times that especially will have an accumulation of material include after winter snow melt and after leaf drop in the fall. Vacuums used on paver systems with bedding material should be able to remove sediments and organic matter without removing the bedding aggregate. If bedding aggregate is removed, it should be replaced. Preventing clogging also involves managing adjacent vegetated and landscaped areas. These area should be maintained in healthy vegetation. Soil, mulch and other landscaping materials should never be stored or stockpiled directly on the pavement. Construction equipment should not be driven over or stored on the pavement.

Snow and Ice Removal. No sand or cinders should be used on pervious pavements. Instead winter maintenance should focus on timely snow plowing and judicious use of deicing materials. Deicing materials present a problem in any pavement system due to their solubility and history of building up to levels that are toxic to plant and animal life. In pervious pavements, high salt use has an increased potential of reaching groundwater sources, but case studies of pervious pavements have shown a reduced need for deicing material to be applied to pervious pavements due to the effects of a warmer subbase. The operation and maintenance plan should provide guidelines for reduced salt use responsive to the actual ice on the pavement rather than typical rates applied on conventional pavements in the Midwest. Snow should not be stockpiled on the pavement. The operation and maintenance plan should show where snow will be pushed or stockpiled during plowing. The operation and maintenance plan should detail the blade depth that plow operators should use, because in some instances, such as grid pavements, snow plow operators may need to raise the blade slightly to avoid dislodging the surface. In every case, care should be taken with snow plowing to keep from gouging the pavement or dislodging aggregate or pavers.

Repair pervious pavements appropriately. Areas may be repaired using the same treatment as the original pervious pavement application or, in the case of porous asphalt or pervious concrete, small areas (not the lowest area on a sloping section) can be replaced with standard (impermeable) pavement. In that case the stone bed of the entire pavement will continue to provide storage and infiltration as designed. In no case should seal coats or new impermeable pavement layers be applied, as is typical in traditional asphalt pavements.

Inspection Items. The following are suggested items for inspection and are adapted from CSN, 2010:

- Using the observation well, observe the rate of drawdown in the practice. Measure the water level in the observation well following a storm event exceeding one half inch of rainfall. This should be done immediately after the storm, recording the precipitation amount, the time of the measurement and the water level in the well. Observe and record the water level after 24, 48 and 72 hours. Actual expected performance will depend on the soils and the intended performance of the design. If the subgrade soils were hydrologic soil group D, there may still be water standing in the reservoir layer after 48 or 72 hours. There should not be standing water above the elevation of the underdrain, and this would indicate problems with the outlet or underdrain system being clogged. Assess potential clogging of the subgrade soils and geotextile by comparing the actual drawdown rate to the intended or design performance of the reservoir layer.
- Observe the pavement surface during and after rain for evidence of ponding, deposited sediments, leaves or debris. Address any signs of clogging or accumulated fine material

by performing vacuum maintenance.

•Inspect the structural integrity of the pavement surface for damage such as missing infill material or broken pavers, spalling, rutting, or slumping of the surface. Any adversely affected areas should be repaired as soon as possible.

•Check contributing impervious areas and their associated pretreatment or runoff control structures for sediment buildup and structural damage. Remove sediment as needed.

•Inspect adjacent and contributing drainage area for sources of sediment or areas that may need better stabilization with erosion control.

Typical Maintenance Activities	Anticipated Schedule
Avoid sealing with construction sediments	During construction & long-term
Water vegetated grid pavement areas and adjacent vegetated areas to ensure good growth	As necessary during first growing season
Avoid sealing or repaving with non-porous materials	Long-term
Clean pavement to ensure pavement is free of debris and sediments	As needed (at least twice a year)
Check to see that pavement dewaters during large storms and does not pond into surface (check observation well for appropriate water levels)	After large storms
Inspect upland and adjacent vegetated areas. Seed & straw bare areas.	As needed
Inspect pavement surface for structural integrity and areas in need of repair. Repair as needed.	Annually

Table 2.11.7: Typical maintenance activities for permeable pavement (adapted from WMI, 1997)

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CHAPTER 3

Stream Rehabilitation and Restoration

To be released at a later date, see Appendix 7 for limited references.

CHAPTER 4

Permanent Runoff Control

Permanent runoff controls convey water in a manner that is stable and doesn't contribute sediment and additional pollutants to runoff. As land development occurs and portions of the natural drainage patterns are changed to manage runoff, permanent runoff control practices such as diversions, level spreaders, grassed swales and outlet protection are used to protect against erosion, safely route flows, dissipate high energy flows and in some cases provide water quality benefits. Generally permanent runoff controls must safely convey the community's prescribed design storm or at least a 10-year frequency storm.

Lands previously used for farming often have subsurface drainage systems, which must continue to serve upland areas. Construction in these areas is bound to uncover drainage systems and disrupting these can cause severe drainage problems to adjoining land. So every effort should be made to locate drainage lines prior to construction and to reroute them during construction. These systems should not be used as stormwater runoff outlets, since they were not designed to function as storm drains. Adding surface water will likely exceed the capacity of the tile system, cause it to fail and subsequently cause adjoining land to suffer drainage problems.

4.1 Grassed Swale

Description

Grassed swales are constructed channels shaped and established with suitable vegetation in order to convey stormwater runoff without allowing channel erosion.

Condition Where Practice Applies

This practice is applicable where added capacity and protection by vegetation are needed to control erosion from concentrated runoff, to improve drainage, or to convey stormwater.

This practice applies generally to small channels having flow only during storm events.

This practice is not applicable in larger ephemeral streams where grass cannot be established and maintained. Chapter 3 Stream Channel Rehabilitation or further channel restoration resources should be referenced for larger channels having seasonal low perennial flow.

Use caution when design flow for the swale is greater than 100 cubic feet per second (cfs) from a 10-yr.-frequency storm. Generally, grassed swales are suitable for drainage areas less than 100 acres in flat to gently rolling terrain. In steeper terrain, it may be more difficult even on smaller drainage areas to design a stable waterway.

Planning Considerations

Constructed Channels vs. Natural Drainageways

Discretion must be used when replacing natural channels with constructed channels. Natural drainage systems, even small intermittent and ephemeral drainageways, provide many hydraulic and environmental benefits not duplicated by constructed channels. See the introduction to Stream Practices for more discussion of natural channel design.

Permits

A construction permit may be required by the local government. Additionally, the U.S. Army Corps of Engineers and the Ohio Environmental Protection Agency, through Sections 404 and 401, respectively, of the Clean Water Act, may require a permit for grassed swales that are located adjacent to a stream. It is best to contact your local Soil and Water Conservation District (SWCD) office to determine what both agencies' permit requirements are for your project.

Water Quality

Grassed swales are designed to reduce erosion and therefore provide a limited water quality benefit. Swales may be modified to store a water quality volume by adding weirs or check dams in order to detain and treat runoff for a minimum of 24 hours.

Stable Outlet

The swale should not be constructed until a suitable stable outlet is in place, and upstream erosion control is in place.

Design Criteria

Grassed swales shall be planned, designed and constructed to comply with all Federal, State, and local laws and regulations.

Runoff

Runoff computation will be based upon the most severe soil and cover conditions that will exist in the area draining into the swale during the planned life of the structure. Use the NRCS Technical Release 55 (TR 55) or other suitable method shall be used to determine peak rate of runoff.

Capacity

The channel's capacity shall be adequate to carry the peak rate of runoff from a 10-yr. frequency storm prior to out of bank flow. Out of bank flows may be permitted in short sections of a reach to facilitate alignment or to minimize grade changes, as long as positive drainage to the swale is maintained, and flow will continue along the swale re-entering the swale prior to reaching the outlet. Where high-hazard conditions exist, higher frequency storms should be chosen to provide protection compatible with conditions. Grassed swales designed to protect residences and businesses, shall have out of bank capacity to carry the peak rate of runoff prior to flow inside adjacent planned residences or businesses.

Cross Section Shape

- *Parabolic channels* most closely approximate natural flow characteristics at low as well as high flows. Although generally preferred for esthetic reasons, design and construction procedures are more complex.
- *Trapezoidal channels* often are used where the quantity of water to be carried is large and velocities high. Channels constructed to treat stormwater runoff should be trapezoidal in shape to promote settling and infiltration. Side slopes that are 3 to 1 or flatter are recommended. Consider future maintenance when designing the shape of trapezoidal channels.

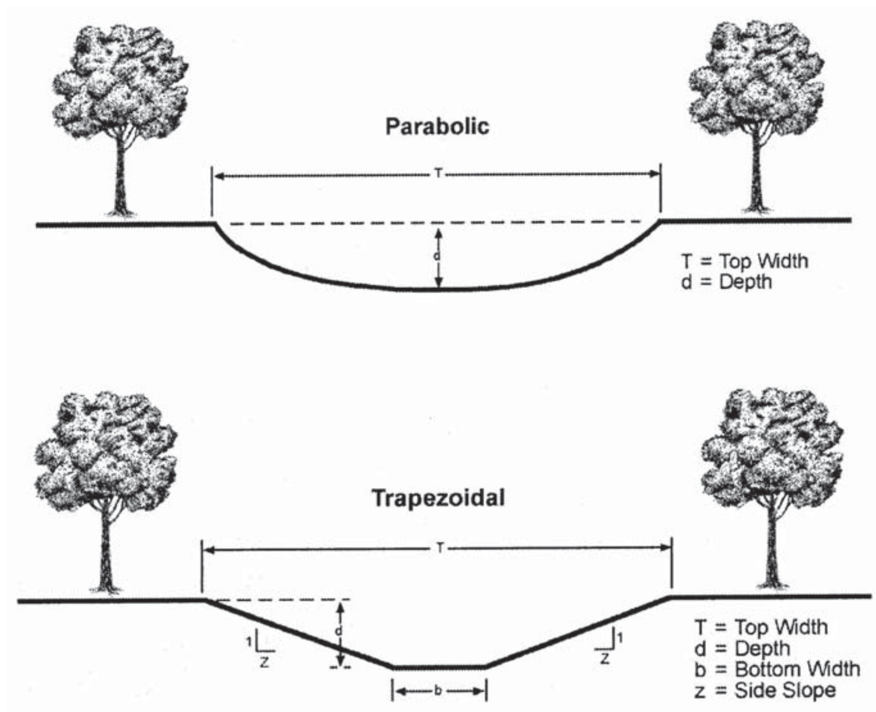


Figure 4.1.1

Special Considerations

Where out-of-bank flow would not cause erosion, property damage or flood damage, no minimum size channel is required. These conditions will most often occur in areas with little slope and established woody vegetation.

Design Velocity of Vegetative Lining:

Channels shall be designed so that the velocity of flow expected from a 10-year frequency storm does not exceed the permissible velocity for the type of lining used (see the table below). Manning's Equation or other suitable method should be used to determine design velocity.

Table 4.1.1 Grass Lining

Maximum Flow Velocity for a 10-Yr. Frequency Storm				
Soil		Maximum Velocity (fps)		
Texture	Type	Seed & mulch	Seed & Matting	Sod
Sand, Silt, Sandy Loam, Silt Loam	Sand	1.5	3.0	3.5
Silty Clay Loam, Sandy Clay Loam	Firm Loam	2.0	4.0	4.0
Clay	Clay	2.5	4.0	5.0
N/A	Gravel	3.5	5.0	6.0
N/A	Weathering Shale	4.5	5.0	N/A

Note: Generally soil texture can be determined from soil surveys. For channels on fill, soils should be tested.

Establishing Vegetation

All grassed swales shall be vegetated or otherwise stabilized, as soon as possible after construction. Stabilization should be done according to the appropriate Standards and Specifications for Vegetative Practices (e.g. Permanent Seeding, Mulching, Matting)

- *For design velocities of less than 3.5 fps,* seeding and mulching may be used for the establishment of the desired vegetation. Mulch netting should be used to protect the seeding during establishment. It is recommended that when conditions permit temporary diversion or other means be used to prevent water from entering the grassed swale during the establishment of vegetation.
- *For design velocities of more than 3.5 fps,* the grassed swale shall be stabilized with seeding protected by erosion control matting or blankets, or with sod. It is recommended that when conditions permit temporary diversion or other means be used to prevent water from entering the grassed swale during the establishment of vegetation.

Check Dams

Check dams may be incorporated to increase channel stability by decreasing flow velocities, and reducing erosion and headcutting. Check dams are grade control structures constructed out of durable material (i.e. rock riprap) across the swale cross section to prevent headcutting. Check dams should be used where they will not be considered a nuisance or create a high maintenance burden. See Chapter __ - Water Quality Swale for planning and design details that could be used to maximizing the detention time within the grassed swale to enhance water quality benefits.

Drainage

Designs for a site having prolonged flows, a high water table, or seepage problems shall include Subsurface Drains, Rock Lined Waterway, or other suitable measures to avoid saturated conditions. See Chapter 4, part 7 Subsurface Drains and Chapter 4, part 3 Rock Lined Channel, for planning and design details.

Offset subsurface drains at least _ of the designed top width from the centerline of the swale. The drain's flowline should be at least 1 foot below the centerline grade and maintain at least 2 feet of cover. Subsurface drains should be installed on both sides of the swale if a high water table or other site conditions will create wetness on both sides. Orifice plates or other acceptable means should be used to prevent pressure flow in the subsurface drain as necessary.

Outlets

All grassed swales shall have a stable outlet with adequate capacity to prevent ponding or flooding damages.

In cases where the grassed swale outlets into a larger ditch or stream with a continual or seasonal base flow, protection of that portion of the grassed waterway / conveyance channel / swale affected by this wet condition is necessary. This may be accomplished by installation of use of a rock lined outlet or grade stabilization structure (see rock channel protection).

Maintenance

A maintenance program shall be established to maintain capacity, vegetative cover, and associated structural components such as inlets, outlets, and tile lines. Items to consider in the maintenance program include:

- Determine responsible party to inspect and maintain the channel after construction
- Protect the channel from damage by equipment and traffic
- Fertilize annually to and maintain a vigorous stand of grass
- Mow the channel regularly to maintain a healthy and vigorous stand of grass
- Inspect grassed swales regularly, especially following heavy rains
- Repair damage to channels immediately. Damaged areas will be filled, compacted, and seeded immediately. All broken subsurface drains should be repaired
- Remove sediment deposits to maintain capacity of grassed swale. Seed and mulch any bare areas that develop. Note: excessive deposition or erosion of the swale may indicate the need to consider changes to the current design that will be appropriate to the water and sediment transport.
- Easements should be obtained to ensure the channel is maintained as constructed.

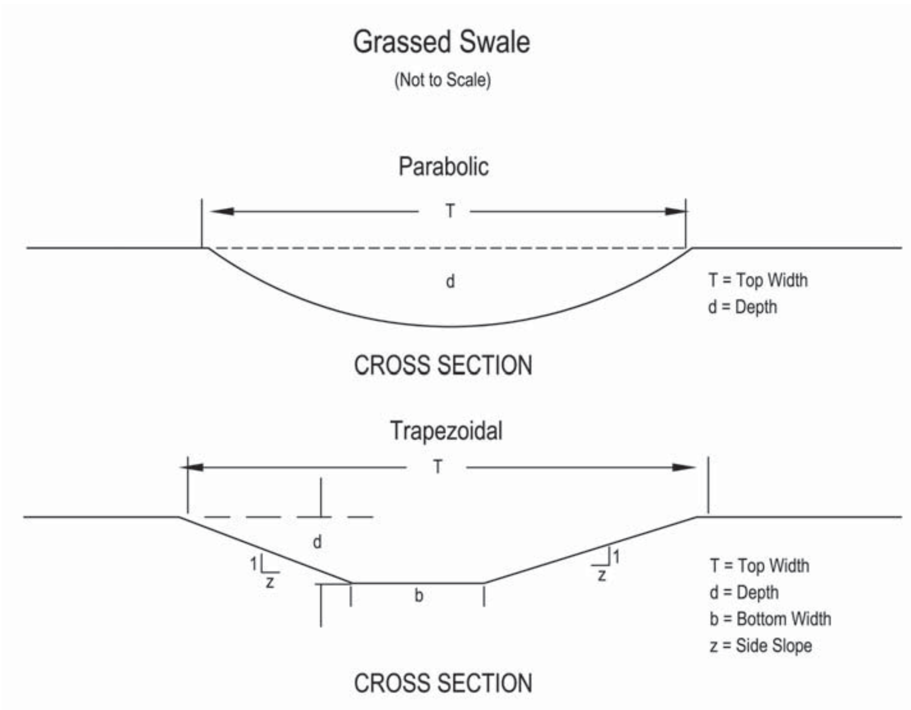
References

Additional guidance for evaluation, planning, and design of grassed swales is given in:

- NRCS Ohio Practice Standard 412, Grassed Waterway.
- NRCS Engineering Field Handbook (EFH) Part 650, Chapter 7 - Grassed Waterways.
- Agricultural Handbook 667, Stability Design of Grass-lined Open Channels.

Specifications
for

Grassed Swale



1. All trees, brush, stumps, and other unsuitable material shall be removed from the site.
2. The channel shall be excavated and shaped to the proper grade and cross section.
3. Fill material used in the construction of the channel shall be well compacted in uniform layers not exceeding 9 inches using the wheel treads or tracks of the construction equipment to prevent unequal settlement.
4. Excess earth shall be graded or disposed of so that it will not restrict flow to the channel or interfere with its functioning.
5. Stabilization shall be done according to the appropriate specifications for permanent seeding, vegetative practices, sodding and matting.
6. Construction shall be sequenced so that newly constructed channels are stabilized prior to becoming operational. To aid in the establishment of vegetation, surface water may be prevented from entering the newly constructed channel through the establishment period.
7. Gullies that may form in the channel or other erosion damage that occurs before the grass lining becomes established shall be repaired without delay.

4.2 Level Spreader

Description

A level spreader is a constructed weir that is shaped or graded flat perpendicular to the direction of flow. Level spreaders are used to convert concentrated flow to sheet flow over nearly level areas without causing erosion, formation or gullies, or flooding.

Condition Where Practice Applies

This practice applies to sites where:

1. Small concentrated flows, less than 30 cfs from a 10-yr. frequency storm, can be converted to sheet flow using a level spreader
2. The outlet area below the level spreader is stable with dense vegetation with a slope less than 10%. The soils are nonerosive and gully formation is not a concern.
3. A level spreader can convert runoff from an impervious surface (i.e. parking lot) or concentrated runoff from curb cuts or roof downspouts to shallow uniform sheet flow
4. Concentrated flows from storm drains, or diversions can be released onto a nearly flat natural densely vegetated area
5. The level lip of the spreader can be constructed in undisturbed soil
6. The level spreader is needed in conjunction with another measure (i.e. vegetated filter strip, detention pond, etc.)

Planning Considerations

The following benefits and impacts of level spreaders should be considered where they are planned:

- Level spreaders are relatively low cost structures that can uniformly disperse impervious surface runoff, roof downspout runoff, or other small volumes of concentrated flow.
- Runoff containing high sediment loads must be treated by a sediment trapping device prior to release into the level spreader
- Level spreaders must be placed where there would be no traffic over the spreader to assure that the level lip remains level and undisturbed
- Level spreaders can be used below pipe outlets where the flow can be converted to and continue as sheet flow. However, the pipe outlet must be stabilized with outlet protection prior to release of runoff into the level spreader.

Design Criteria

Capacity

The design capacity of the level spreader shall be estimated by determining the peak rate of runoff from a 10-yr. frequency storm. The design flow should not be greater than 30 cubic feet per second (cfs) from a 10-yr.-frequency storm.

Spreader Dimensions

Select the length and depth of the spreader from Table 4.2.1 below.

- The minimum width (W) is in the direction that is perpendicular to the flow.
- The minimum depth (D) of the level spreader shall be at least 0.5 feet measured down from the level lip. Depth may be greater to increase temporary storage capacity, improve trapping of debris, and enhance settling of any suspended solids based on erosion potential or other site conditions.

Table 4.2.1 Level Spreader Dimensions

Flow Rate (cfs)	Minimum Depth – D (ft)	Minimum Width – W (ft)
0 – 10	0.5	10
10 – 20	0.6	20
20 – 30	0.7	30

The level lip of the spreader must be constructed completely level (0% grade) to insure uniform spreading of the runoff over the entire length of the spreader.

Flows released from level spreaders must outlet onto undisturbed stable areas with a slope not exceeding 10%, where sheet flow are maintained and concentrated flow prevented.

When constructing a level spreader as an outlet for a diversion, the last 20 feet of the diversion should be used to smoothly transition the width of the diversion to the width of the spreader to ensure uniform outflow. The grade of the channel for the last 20 feet of the diversion entering the level spreader shall be 1.0% or less.

Side Slopes

The sides of the spreader shall be tied into higher ground to prevent flow around the spreader. Side slopes shall be 2 to 1 (horizontal to vertical) or flatter.

Weir Materials

- For design flows less than 4 cfs, the level spreader lip may be vegetated natural earth (not fill).

  The ***vegetated lip spreader*** shall be protected using an erosion control blanket (installed according to manufacturers recommendations) to prevent erosion and allow vegetation to become established. The blanket shall start a minimum of 4 feet above the lip and extend at least 1 foot downstream over the spreader lip secured with heavy-duty staples with the downstream and upstream ends buried at least 6 inches in a vertical trench.

- For design flows greater than 4 cfs, the level spreader lip must be constructed of rigid, durable, non-erodible material (i.e. riprap, concrete, or precast block or geosynthetic materials).

  The ***rigid lip spreader*** constructed of riprap shall meet ODOT Type D riprap and shall be carefully installed with a 2-foot wide level lip. An apron with existing vegetation shall extend downstream from the rigid lip at least 3 feet. The riprap shall be a minimum of 12 inches thick. Spread gravel or soil over top of the placed riprap surface to fill the voids and interlock the riprap together. A rigid lip spreader constructed from other durable, non-erodible material (ie –concrete curbing) shall be constructed of material that is anchored securely at least 4 inches below existing ground to prevent displacement. An apron of AASHTO No. 1 stone shall be placed adjacent to and downstream from the rigid lip at least 3 feet. The top of the stone shall be at the same elevation as the top of the lip.

Use with Pipe Outlet Protection

Level spreaders can be used below pipe outlets where the flow can be converted to and continue as sheet flow. However, the pipe outlet must be stabilized with outlet protection prior to release of runoff into the level spreader.

Establishing Vegetation

All level spreaders shall be vegetated or otherwise stabilized, as soon as possible after construction. Stabilization should be done according to the appropriate Standards and Specifications for Vegetative Practices (e.g. Permanent Seeding, Mulching, Matting).

Maintenance

A maintenance plan shall be established to maintain the level spreader, its capacity, vegetative cover, and other associated structural components such as outlets, headwalls or rock.

Items to consider in the maintenance program include:

- Determine responsible party to inspect and maintain the practice after construction
- Protect the practice from damage by equipment and traffic
- Fertilize the vegetated area annually to and maintain a vigorous stand of grass
- Mow the vegetated area to maintain a healthy and vigorous stand of grass.
- Check the level spreader periodically to verify that the spreader is distributing flow uniformly. If problems are noted, make repairs to ensure even flow over the level lip.
- Repair damage to the level spreader immediately. Missing materials should be replaced as soon as possible. Seed and mulch any bare areas that develop.
- Remove sediment and debris that have accumulated.

- Easements, or other means, should be obtained to ensure the level spreader is maintained as constructed.

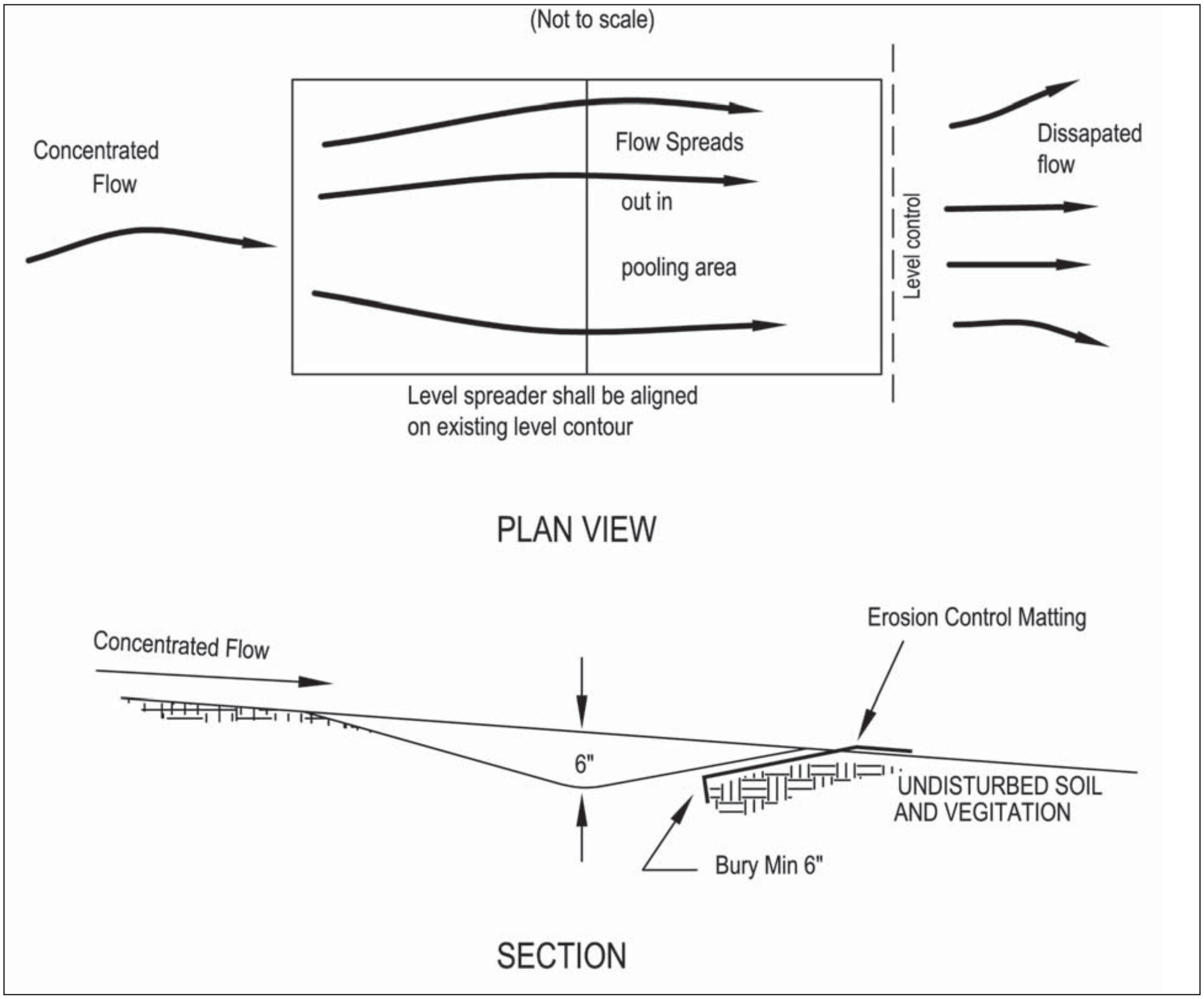
References

Additional guidance for evaluation, planning, and design of level spreaders is given in:

- Illinois Urban Manual: A Technical Manual Designed for Urban Ecosystem Protection and Enhancement, prepared for the Illinois EPA by Illinois NRCS
- Ohio Rainwater and Land Development Manual, Second Edition 1996
- NRCS Design Note 24, Guide for Use of Geotextiles

Specifications
for

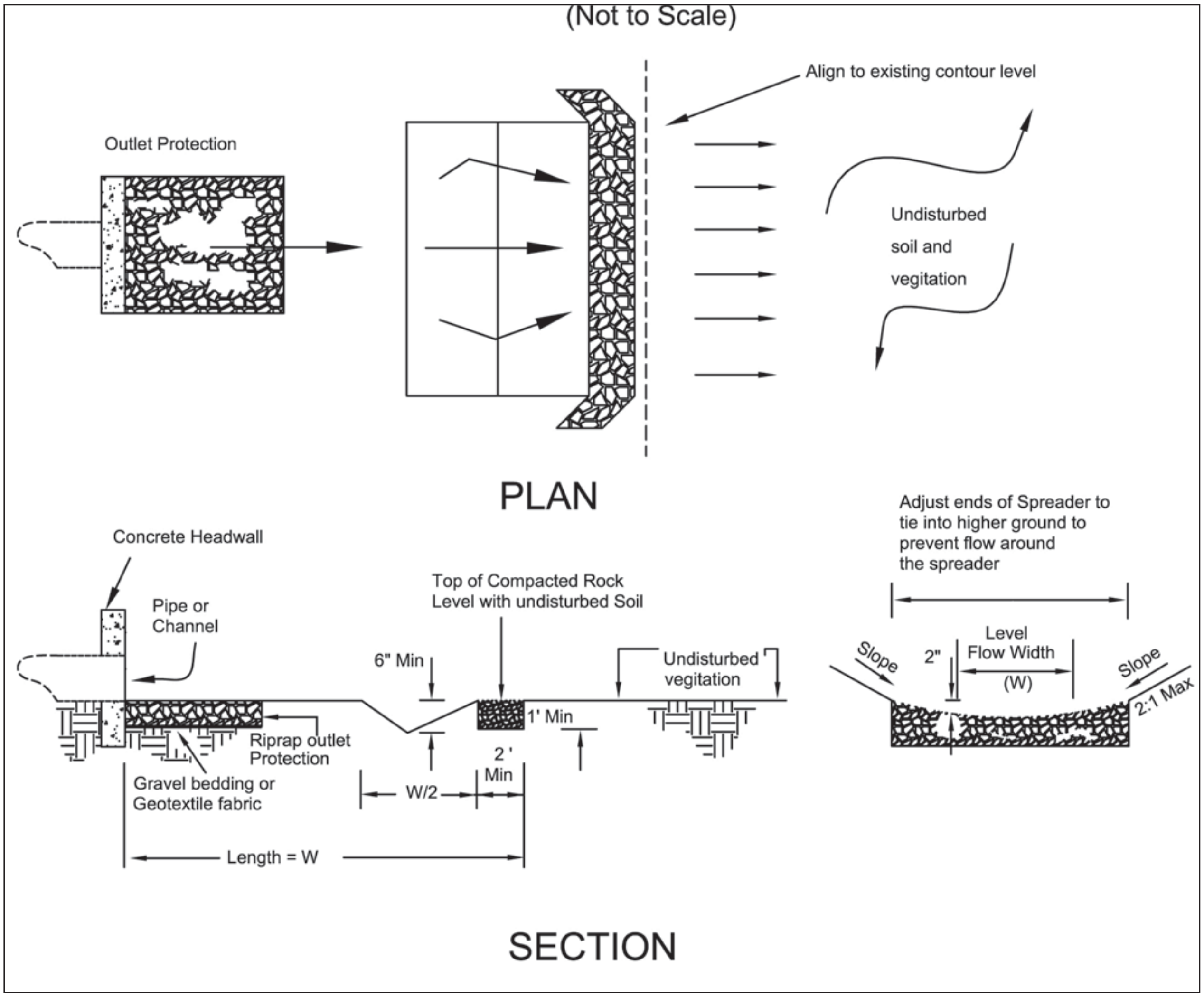
Vegetated Level Spreader



1. Construct level spreader on a level grade to ensure uniform spreading of storm runoff.
2. Level spreaders must be constructed on undisturbed soil, NOT on fill.
3. The level spreader must outlet to erosion-resistant areas with established existing vegetation.
4. Vegetated lip spreaders shall be protected using an erosion control blanket installed according to manufactures' recommendations. The blanket shall start a minimum of 4 feet above the lip and extend at least 1 foot downstream over the spreader lip, secured with heavy-duty staples and the downstream and upstream ends buried at least 6 inches in a vertical trench.
5. Fertilizing, seeding, and mulching shall conform to the recommendations in the applicable vegetative specification.

Specifications
for

Rigid Lip Level Spreader



1. Construct level spreader on a level grade to ensure uniform spreading of storm runoff.
2. Level spreaders must be constructed on undisturbed soil, NOT on fill.
3. The level spreader must outlet to erosion-resistant areas with established existing vegetation.
4. Rock shall be ODOT Type D where 50% of the material by weight is larger than 6 inches, and 85% of the material by weight is larger than 3 inches but less than 12 inches.
5. Rock in level spreader shall be compacted with at least two passes of heavy machinery to prevent further settling. Spread gravel or soil over top of the placed riprap surface to fill the voids and interlock the riprap together.
6. Fertilizing, seeding, and mulching shall conform to the recommendations in the applicable vegetative specification.

4.3 Rock Lined Channel

Description

A channel that is shaped or graded and protected with an erosion resistant rock riprap underlain with filter or bedding material used to convey stormwater runoff without allowing channel erosion. Rock channel protection provides for the safe conveyance of runoff from areas of concentrated flow without damage from erosion or flooding, where vegetated waterway / conveyance channel / swales would be inadequate. Rock lined channel may also be necessary to control seepage, piping, and sloughing or slides. The riprap section extends up the side slopes to designed depth. The earth above the rock should be vegetated or otherwise protected.

Conditions Where Practice Applies

This practice applies where the following conditions exist:

- Concentrated runoff will cause erosion unless a liner is provided
- Steep grades, wetness, seepage, prolonged base flow, or piping would cause erosion
- Damage by vehicles or animals will make the establishment or maintenance of vegetation difficult
- Soils are highly erosive or other soil or climatic conditions preclude the use of vegetation
- Velocities are expected that will erode the channel or outlet without protection

Caution should be used when design flow greater than 100 cubic feet per second (cfs) from a 10-yr.-frequency storm is expected. Chapter __ - Stream Channel Restoration, should be referenced for planning and design of larger channels.

Planning Considerations

Permits

A construction permit may be required by the local government. Additionally, the U.S. Army Corps of Engineers and the Ohio Environmental Protection Agency, through Sections 404 and 401, respectively, of the Clean Water Act, may require a permit for rock lined channel / outlet that are located adjacent to a stream. It is best to contact your local Soil and Water Conservation District (SWCD) office to determine what both agencies' permit requirements are for your project.

Water Quality

Rock lined channels and outlet protection provide water quality benefits by providing channel stability, prevention of excessive erosion, and limiting subsequent downstream sedimentation.

Design Criteria

Runoff

Runoff computation will be based upon the most severe soil and cover conditions that will exist in the area draining into the channel during the planned life of the structure. Use the NRCS Technical Release 55 (TR 55) or other suitable method shall be used to determine peak rate of runoff.

Capacity

The design capacity of the rock lined channel shall be adequate to carry the peak rate of runoff from a 10-yr. frequency storm. Where high-hazard conditions exist, higher frequency storms should be chosen to provide protection compatible with conditions. The rock-lined channel must have design capacity as required if it to be used as an outlet for a grassed waterway, diversion, terrace, or other measure. Capacity shall be computed using Manning's Equation with a coefficient of roughness "n" listed in the "rock size" table below.

Rock-lined channels / outlets shall be designed by accepted engineering methods such as the Federal Highway Administration Circular No. 15 or Figure 2-1 (Maximum depth of Flow for Riprap Lined Channels) that can be used to determine rock size using flow depth and velocity obtained from Manning's equation. Procedures are also available in the NRCS Engineering Field Handbook.

Velocity

Table 4.3.1 Maximum Design Velocity

Design Flow Depth	Maximum Velocity
0 - 0.5 ft	25 fps
0.5 – 1.0 ft	15 fps
> 1.0 ft	10 fps

Cross Section Shape

The cross sectional shape of rock lined waterway / outlets shall be parabolic, trapezoidal, or triangular.

- *Parabolic channels* most closely approximate natural flow characteristics at low as well as high flows. Although generally preferred for esthetic reasons, design and construction procedures are more complex.
- *Trapezoidal channels* often are used where the quantity of water to be carried is large and velocities high. The steepest permissible side slopes, horizontal to vertical, shall be 2 to 1.
- *Triangular shaped channels* generally is used where the quantity of water to be handled is relatively small, such as roadside ditches. The steepest permissible side slopes, horizontal to vertical, shall be 2 to 1.

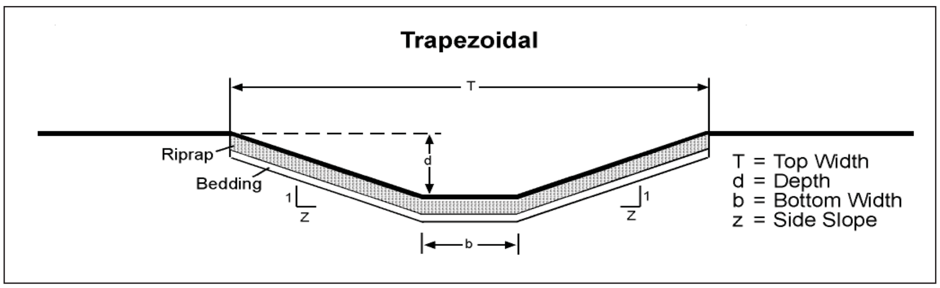


Figure 4.3.1

Rock Lining

The rock-lined channel shall consist of the rock riprap layer and an underlying filter or bedding. Minimum thickness of the rock riprap layer shall be the maximum stone size. Stone used for riprap shall be dense and hard enough to withstand exposure to air, water, freezing and thawing. Figure 4.3.2 gives the maximum depth of flow for riprap lined channels. Rock riprap must have a well-graded distribution and be placed in a to obtain a solid, compact layer of riprap. This may require some hand placing and tamping with construction equipment. Spreading gravel or soil over top of the placed riprap surface will fill the voids by interlocking the riprap together.

Filter or Granular Bedding

Filter or granular bedding must be placed beneath all riprap to prevent the underlying soil from eroding and undermining the riprap, and to collect seepage and base flow. Minimum bedding thickness shall be 4 inches. Use of large size riprap may necessitate the use of a thicker bedding layer or 2 differently sized bedding layers. Care should be taken to select a granular bedding that that is suitable with the subgrade material.

Table 4.3.2 Rock Riprap Size

Type of Rock or Riprap (ODOT)	"n" value	Size of Rock	
		50% by weight	85% by weight
Type D	.036	> 6 in.	3 - 12 in.
Type C	.04	> 12 in.	6 - 18 in.
Type B	.043	> 18 in.	12 - 24 in.
Type A	.045	> 24 in.	18 - 30 in.

Adjustments to Naturalize Rock Lining

In order to more closely reflect the nature of the bed of a natural channel, smaller size graded stone may be used to fill the voids left in typical riprap applications.

Besides channel shape and pattern, typical rock lined channels depart from the flow behavior of natural channels by having to much pore space in the rock. Therefore regular flow is often entirely below the surface. This will be improved by extending the gradation of stone down to the gravel-sized material. This addition will increase velocity and reduce capacity slightly; therefore corresponding adjustments should be made.

Geotextile

Geotextile may be used as a filter to be placed beneath the riprap to prevent piping of the soil where wetness, seepage, or prolonged base flow is the reason for lining the channel with riprap. If design of the rock lined channel results in high velocities and steep grades, granular bedding should be used instead of geotextile. Care should be taken to properly anchor the geotextile to prevent unraveling under flowing water. Geotextile shall be woven or nonwoven monofilament yarn and shall meet Class I criteria in the attached table "Requirements for Geotextile".

Maintenance

A maintenance program shall be established to maintain capacity, vegetative cover above the riprap, and associated structural components such as inlets, outlets, and tile lines. Items to consider in the maintenance program include:

- Determine responsible party to inspect and maintain the channel after construction
- Protect the channel from damage by equipment, traffic, or livestock
- Fertilize the vegetated area annually to and maintain a vigorous stand of grass
- Mow the vegetated area to maintain a healthy and vigorous stand of grass.
- Repair damage to channels immediately. Missing riprap should be replaced as soon as possible. All broken subsurface drains should be repaired. Seed and mulch any bare areas that develop.
- Remove sediment and debris that have accumulated.
- Easements, or other means, should be obtained to ensure the channel is maintained as constructed

References

Additional guidance for evaluation, planning, and design of rock lined channels is given in:

- National Cooperative Highway Research Program Report 108 – Tentative Design Procedure for Riprap – Lined Channels
- NRCS Ohio Practice Standard 468, Lined Waterway Or Outlet
- NRCS Engineering Field Handbook, Chapter 6 - Structures
- NRCS Design Note 24, Guide for Use of Geotextiles

Table 4.3.3 Requirements for Geotextiles

Property	Test method	Woven - Class I	Nonwoven - Class I
Tensile strength (pounds) 1/	ASTM D 4632 grab test	200 minimum in any principal direction	180 minimum
Elongation at failure (percent) 1/	ASTM D 4632 grab test	<50	≥ 50
Puncture (pounds) 1/	ASTM D 4833	90 minimum	80 minimum
Ultraviolet light (% residual tensile strength)	ASTM D 4355 150-hr exposure	70 minimum	70 minimum
Apparent opening size (AOS)	ASTM D 4751	As specified, but no smaller than 0.212 mm (#70) 2/	As specified max. #40 2/
Percent open area (percent)	CWO-02215-86	4.0 minimum	---------------
Permitivity sec-1	ASTM D 4491	0.10 minimum	0.70 minimum

1/ Minimum average roll value (weakest principal direction).
2/ U.S. standard sieve size.
Note: CWO is a USACE reference.

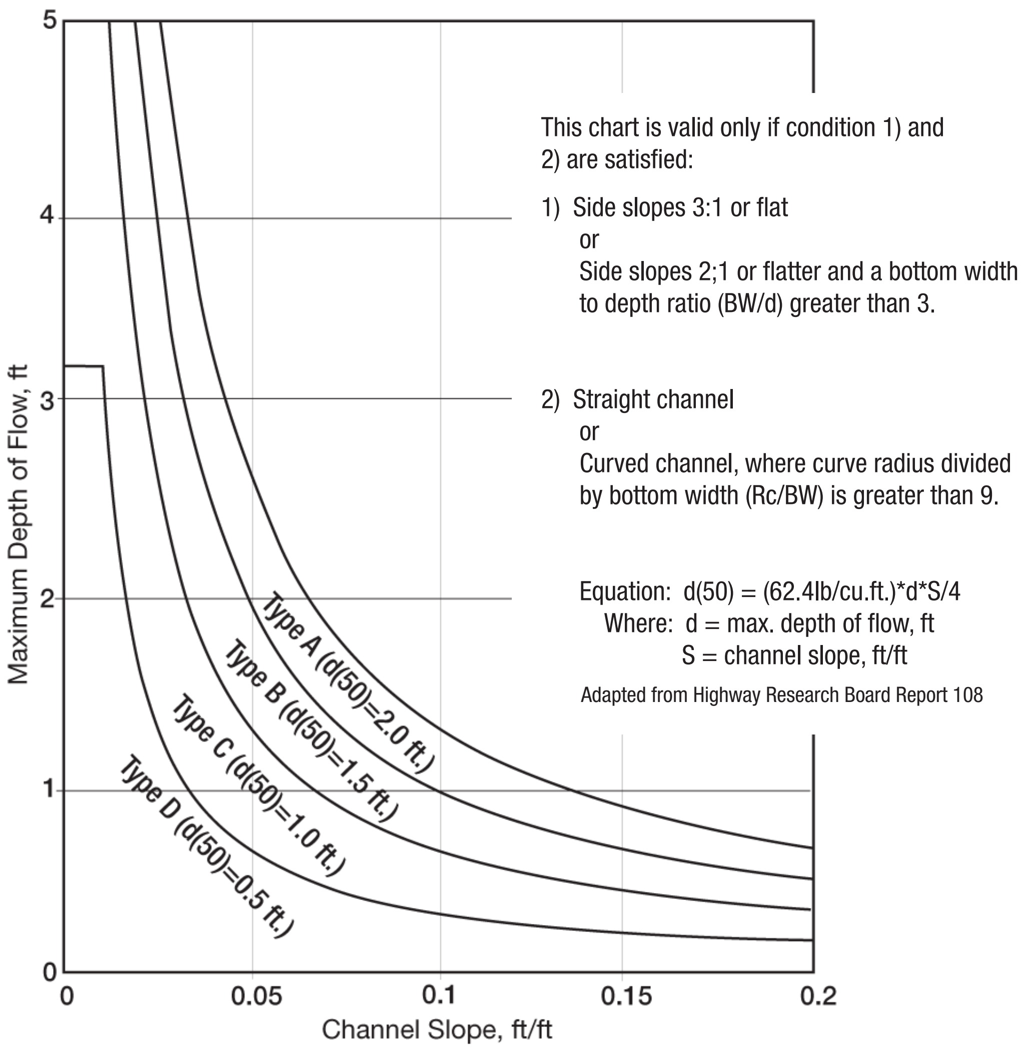
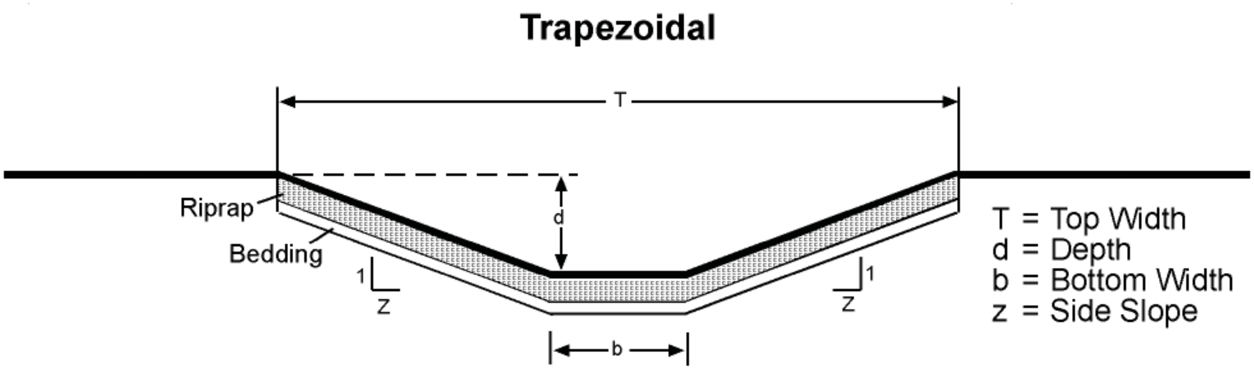


Figure 4.3.2 Maximum Depth of Flow for Riprap Lined Channels

Specifications
for

Rock Lined Channel



1. Subgrade for the filter and riprap shall be prepared to the required lines and grades as shown on the plan. The subgrade shall be cleared of all trees, stumps, roots, sod, loose rock, or other material.
2. Riprap shall conform to the grading limits as shown on the plan.
3. No abrupt deviations from the design grade or horizontal alignment shall be permitted.
4. Geotextile shall be securely anchored according to manufacturers recommendations.
5. Geotextile shall be laid with the long dimension parallel to the direction of flow and shall be laid loosely but without wrinkles and creases. Where joints are necessary, strips shall be placed to provide a 12-in. minimum overlap, with the upstream strip overlapping the downstream strip.
6. Gravel bedding shall be ODOT No. 67's or 57's unless shown differently on the drawings.
7. Riprap may be placed by equipment but shall be placed in a manner to prevent slippage or damage to the geotextile.
8. Riprap shall be placed by a method that does not cause segregation of sizes. Extensive pushing with a dozer causes segregation and shall be avoided by delivering riprap near its final location within the channel.
9. Construction shall be sequenced so that riprap channel protection is placed and functional without delays when the channel becomes operational.
10. All disturbed areas will be vegetated as soon as practical.

4.4 Rock Outlet Protection

Description

A rock or riprap apron typically needed at the outlet of storm drains, culverts, or open channels. Rock Outlet Protection provides an erosion resistant transition area where concentrated or high velocity flows enters less modified channels or natural streams.

Conditions Where Practice Applies

This practice applies where discharge velocities from channels, storm drains or culverts are high enough to erode receiving streams or areas. Suggested areas of application are:

- Outfalls of stormwater detention facilities or sediment traps or basins.
- Constructed channel outlets
- Culvert outlets

This practice is not intended for use on slopes greater than 10% or at the top of cut or fill slopes. Caution should be used when design flows exceed 100 cubic feet per second (cfs) from a 10-yr.-frequency storm..

Planning Considerations

Rock Outlet Protection may be used in conjunction with other practices, such as level spreaders. Rock Outlet Protection and Level Spreaders can both be used at the end of pipe outlets. This practice should be used alone where flow will continue as concentrated flow. Level Spreaders can be used with Rock Outlet Protection only when flow can be converted to and continue as sheet flow.

Permits

A construction permit may be required by the local government. Additionally, the U.S. Army Corps of Engineers and the Ohio Environmental Protection Agency, through Sections 404 and 401, respectively, of the Clean Water Act, may require a permit for an outlet protection that is located adjacent to a stream.

Water Quality

Rock outlet protection may also provide water quality benefits by providing for channel stability, prevention of excessive erosion, and limiting subsequent downstream sedimentation.

Design Criteria

Runoff

Runoff computation will be based upon the most severe soil and cover conditions that will exist in the area draining into the channel during the planned life of the structure. Use the NRCS Technical Release 55 (TR 55) or other suitable method shall be used to determine peak rate of runoff.

Velocity

Outlet protection shall be designed to be stable for discharge velocity expected from a 10-year frequency storm. Where high-hazard conditions exist, higher frequency storms should be chosen to provide protection compatible with conditions. Outlet protection shall meet the following criteria

Design Velocity

Outlet protection shall be designed to be stable for the velocity of flow expected from a 10-year frequency storm. Outlet protection shall be designed to meet the criteria below or by other accepted engineering methods.

Width

The width of the outlet protection shall be the width of the headwall or 4 feet wider than the pipe diameter (2 feet on each side of the pipe).

Bottom Grade

The outlet protection should be constructed with no slope along it length. The elevation on the downstream end of the outlet protection shall be equal to the elevation of the receiving stream or channel.

Length of Rock Outlet Protection and Rock Size

Use the velocity calculated at the pipe outlet, the pipe diameter, and Figure 4.4.1. Outlet Protection Length, to find the length of outlet protection needed and rock size to use.

Rock Lining

The outlet protection shall consist of the rock riprap layer and an underlying filter or bedding. Minimum thickness of the rock riprap layer shall be the maximum stone size. Stone used for riprap shall be dense and hard enough to withstand exposure to air, water, freezing and thawing. Rock riprap must have a well-graded distribution and be placed to obtain a solid, compact layer of riprap. This may require some hand placing and tamping with construction equipment. Spreading gravel or soil over top of the placed riprap surface will fill the voids by interlocking the riprap together.

Table 4.4.1 Rock Riprap Size

Type of Rock or Riprap (ODOT)	"n" value	Size of Rock	
		50% by weight	85% by weight
Type D	.036	> 6 in.	3 - 12 in.
Type C	.04	> 12 in.	6 - 18 in.
Type B	.043	> 18 in.	12 - 24 in.
Type A	.045	> 24 in.	18 - 30 in.

Filter or Granular Bedding

Filter or granular bedding must be placed beneath all riprap to prevent the underlying soil from eroding and undermining the riprap, and to collect seepage and base flow. Minimum bedding thickness shall be 4 inches. Use of large size riprap may necessitate the use of a thicker bedding layer or 2 differently sized bedding layers. Care should be taken to select granular bedding that that is suitable with the subgrade material.

Geotextile

Geotextile may be used as a filter to be placed beneath the riprap to prevent piping of the soil where wetness, seepage, or prolonged base flow is the reason for lining the channel with riprap. If design of the outlet protection results in high velocities and steep grades, granular bedding should be used instead of geotextile. Care should be taken to properly anchor the geotextile to prevent unraveling under flowing water. Geotextile shall be woven or nonwoven monofilament yarn and shall meet Class I criteria in the attached table "Requirements for Geotextile".

Maintenance

A maintenance program shall be established to maintain riprap, vegetative cover above the riprap, and associated structural components such as pipe outlets, and tile lines. Items to consider in the maintenance program include:

- Determine responsible party to inspect and maintain the outlet protection after construction
- Missing riprap should be replaced as soon as possible.
- Protect the outlet protection from damage by equipment and traffic
- Fertilize the vegetated area annually to and maintain a vigorous stand of grass
- Mow the vegetated area to maintain a healthy and vigorous stand of grass.
- Seed and mulch any bare areas that develop.
- Remove sediment and debris that have accumulated.
- Easements, or other means, should be obtained to ensure the channel is maintained as constructed

References

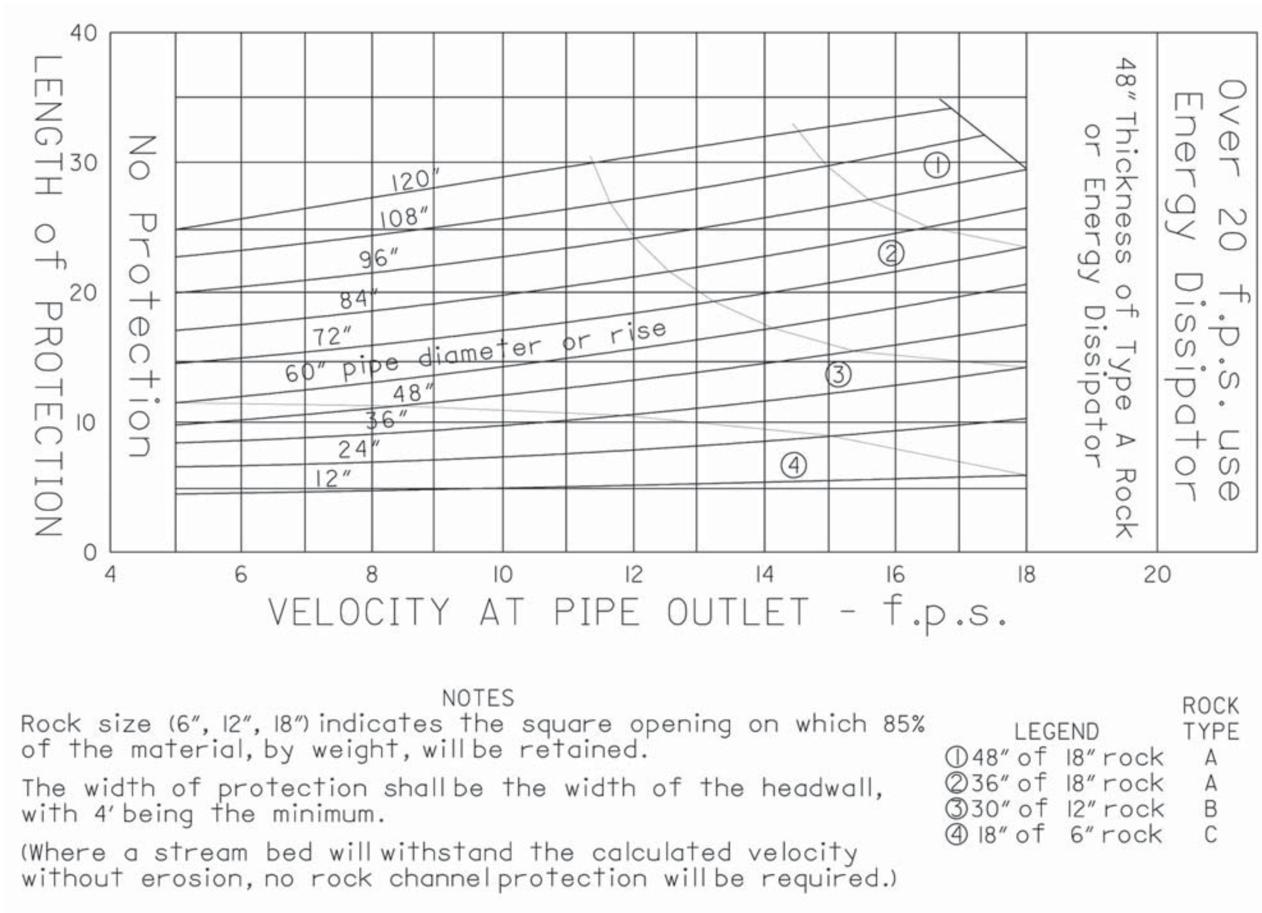
Additional guidance for evaluation, planning, and design of outlet protection is given in:

- NRCS Ohio Practice Standard 468, Lined Waterway Or Outlet
- NRCS Engineering Field Handbook, Chapter 6 - Structures
- NRCS Design Note 24, Guide for Use of Geotextiles
- ODOT Location and Design Manual, Rock Channel Protection at Culvert and Storm Sewer Outlets

Table 4.4.2 Requirements for Geotextiles

Property	Test method	Woven - Class I	Nonwoven - Class I
Tensile strength (pounds) 1/	ASTM D 4632 grab test	200 minimum in any principal direction	180 minimum
Elongation at failure (percent) 1/	ASTM D 4632 grab test	<50	≥ 50
Puncture (pounds) 1/	ASTM D 4833	90 minimum	80 minimum
Ultraviolet light (% residual tensile strength)	ASTM D 4355 150-hr exposure	70 minimum	70 minimum
Apparent opening size (AOS)	ASTM D 4751	As specified, but no smaller than 0.212 mm (#70) 2/	As specified max. #40 2/
Percent open area (percent)	CWO-02215-86	4.0 minimum	---------------
Permitivity sec-1	ASTM D 4491	0.10 minimum	0.70 minimum

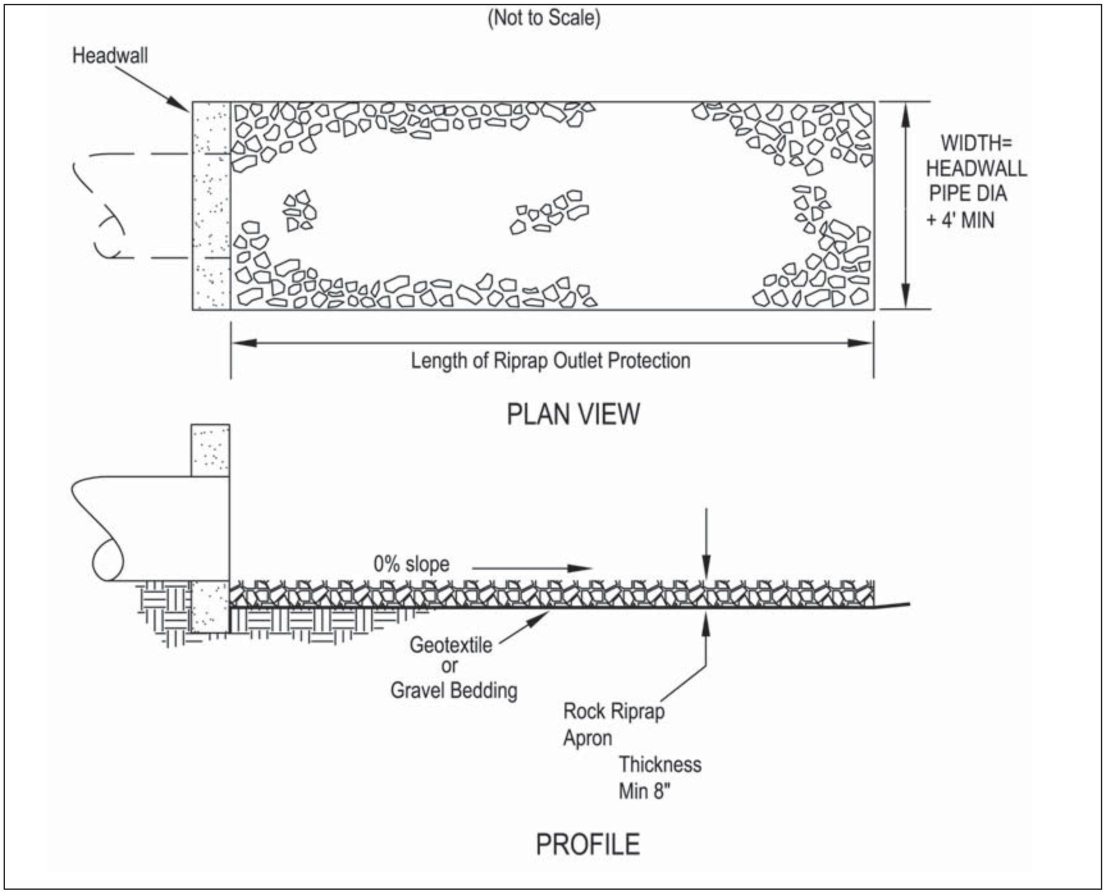
1/ Minimum average roll value (weakest principal direction).
2/ U.S. standard sieve size.
Note: CWO is a USACE reference.



Source: ODOT Location and Design Manual, Rock Channel Protection at Culvert and Storm Sewer Outlets

Figure 4.4.1 Length of Rock Outlet Protection and Rock Size

Specifications
for
Rock Outlet Protection



1. Subgrade for the filter or bedding and riprap shall be prepared to the required lines and grades as shown on the plan. The subgrade shall be cleared of all trees, stumps, roots, sod, loose rock, or other material.
2. Riprap shall conform to the grading limits as shown on the plan.
3. Geotextile shall be securely anchored according to manufacturers' recommendations.
4. Geotextile shall be laid with the long dimension parallel to the direction of flow and shall be laid loosely but without wrinkles and creases. Where joints are necessary, strips shall be placed to provide a 12-in. minimum overlap, with the upstream strip overlapping the downstream strip.
5. Gravel bedding shall be ODOT No. 67's or 57's unless shown differently on the drawings.
6. Riprap may be placed by equipment but shall be placed in a manner to prevent slippage or damage to the geotextile.
7. Riprap shall be placed by a method that does not cause segregation of sizes. Extensive pushing with a dozer causes segregation and shall be avoided by delivering riprap near its final location within the channel.
8. Construction shall be sequenced so that outlet protection is placed and functional when the storm drain, culvert, or open channel above it becomes operational.
9. All disturbed areas will be vegetated as soon as practical.

4.5 Diversion

Description

A permanent channel constructed across the slope with a supporting ridge on the lower side used to divert excess water from one area for use or safe disposal in other areas.

Conditions Where Practice Applies

This practice applies to sites where:

- A permanent diversion is required to control erosion and runoff on down slope developing areas and construction sites
- Runoff from higher areas is causing off site damage
- Surface and shallow subsurface flow is damaging sloping upland.
- A diversion is required as part of a pollution abatement system to protect off site sensitive areas
- Permanent diversions are suitable on flatter gradients. Steeper gradients may require a rock lining or other means of protection
- For a temporary diversion that is needed to divert excess runoff for a short period of time, see the design considerations for Temporary Diversion, Chapter 5.

Planning Considerations

Water Quality

Besides the primary design objective of providing a stable channel, water quality benefits may also be achieved. Diversions may promote settling and infiltration for small storm events, thereby treating runoff. To provide water quality treatment benefits, see Chapter __ - Water Quality Swale for planning and design details.

Location

Locations of diversions shall be determined by topography, outlet conditions, land use, soil type, and length of slope. When diversions are used to intercept subsurface flow or seepage, depth and location of seepage should be used to determine location and spacing of diversions.

A subsurface drain should be used as necessary to establish and maintain vegetative cover.

Design Criteria

Runoff

Runoff computation will be based upon the most severe soil and cover conditions that will exist in the area draining into the waterway during the planned life of the structure. Use the NRCS Technical Release 55 (TR 55) or other suitable method shall be used to determine peak rate of runoff.

Capacity

Diversions protecting undeveloped land shall have a capacity to carry the peak rate of runoff from a 10-yr. frequency storm. Where high-hazard conditions exist, higher frequency storms should be chosen to provide protection compatible with conditions. Diversions designed to protect urban areas, buildings and roads, shall have a capacity to carry the peak rate of runoff from a 25-yr. frequency storm with a freeboard of not less than 0.3 feet.

Cross Section

The diversion channel shall be parabolic or trapezoidal. The diversion shall be designed to have stable side slopes (3 horizontal to 1 vertical or flatter are recommended on both sides). The ridge height shall include a minimum of 0.3 ft of freeboard and a minimum settlement factor of 10% in addition to the design flow depth. The ridge shall have a minimum constructed top width of 4 feet at the design elevation. The minimum cross sectional area shall meet the specified dimensions. The top of the constructed ridge shall not be lower at any point than the design elevation plus the specified amount for settlement.

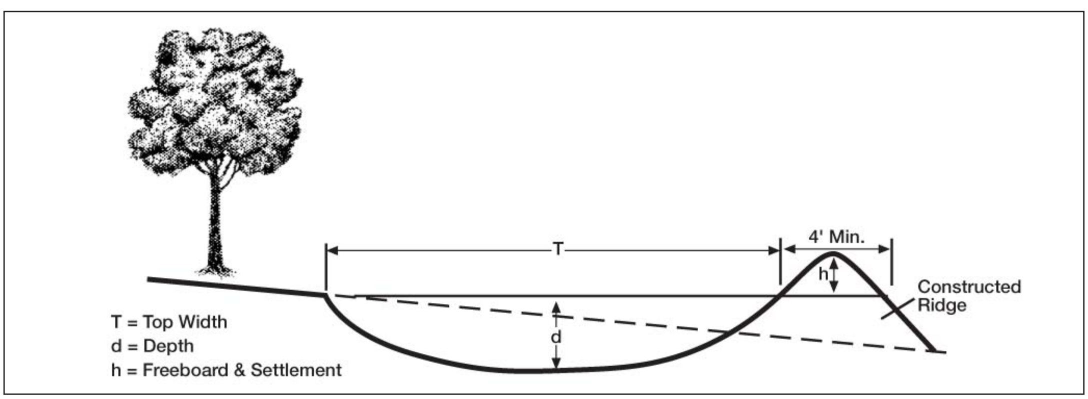


Figure 4.5.1

Grade and velocity

Channel grades shall be as uniform as possible. Special care should be taken in evaluating site conditions for diversions where the grade decreases toward the outlet because of potential sediment deposition problems.

Design Velocity of Vegetative Lining:

Diversions shall be designed so that the velocity of flow expected from a 10-year frequency storm does not exceed the permissible velocity for the type of lining used (see the table below). Manning's Equation or other suitable method should be used to determine design velocity.

Table 4.5.1 Grass Lining Maximum Flow Velocity for a 10-Yr. Frequency Storm

Soil		Maximum Velocity (fps)		
Texture	Type	Seed & Mulch	Seed & Matting	Sod
Sand, Silt, Sandy Loam, Silt Loam	Sand	1.5	3.0	3.5
Silty Clay Loam, Sandy Clay Loam	Firm Loam	2.0	4.0	4.0
Clay	Clay	2.5	40	5.0
N/A	Gravel	3.5	5.0	6.0
N/A	Weathering Shale	4.5	5.0	N/A

Note: Soil texture can be generally determined from the soil surveys. If the channel is on fill, the soil should be tested.

Establishing Vegetation

All diversions shall be vegetated or otherwise stabilized, as soon as possible after construction. Stabilization should be done according to the appropriate Standards and Specifications for Vegetative Practices (e.g. Permanent Seeding, Mulching, Matting).

- For design velocities of less than 3.5 fps, seeding and mulching may be used for the establishment of the desired vegetation. Mulch netting should be used to protect the seeding during establishment. It is recommended that when conditions permit, a temporary diversion or other means be used to prevent water from entering the diversion during the establishment of vegetation.
- For design velocities of more than 3.5 fps, the diversion shall be stabilized with seeding protected by erosion control matting or blankets, or with sod. It is recommended that when conditions permit, a temporary diversion or other means be used to prevent water from entering the diversion during the establishment of vegetation.

Sedimentation

Diversions should not be used below high sediment producing areas unless land treatment practices or structural measures that will prevent damage to the diversion are designed and installed prior to installation of the diversion. If some accumulation of sediment cannot be prevented, then the design shall include extra capacity for the sediment. Accumulation of sediment shall be considered in the maintenance plan for this practice.

Outlets

All diversions shall have a stable outlet with adequate capacity to prevent ponding or flooding damages. The outlet may be a grassed waterway / conveyance channel / swale, stable vegetated area, grade stabilization structure, rock lined waterway / outlet, or stable stream. The outlet must convey runoff to a point where outflow will not cause damage. The design elevation of the water surface in the diversion shall not be less than the water surface in the outlet at the junction when both are operating at design flow.

Maintenance

A maintenance program shall be established to maintain capacity, vegetative cover, and associated structural components such as inlets, outlets, and subsurface drains. Items to consider in the maintenance program include:

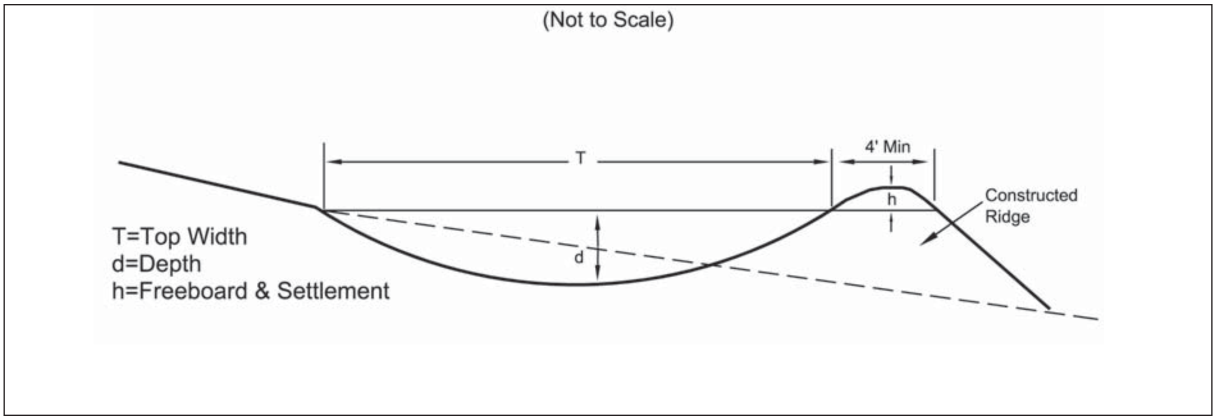
- Determine responsible party to inspect and maintain the diversion after construction
- Protect the diversion from damage by equipment, traffic, or livestock
- Fertilize annually to and maintain a vigorous stand of grass
- Mow the diversion regularly to maintain a healthy and vigorous stand of grass
- Inspect the diversion regularly, especially following heavy rains
- Repair damage to the diversion immediately. Damaged areas will be filled, compacted, and seeded immediately. All broken subsurface drains should be repaired
- Remove sediment deposits to maintain capacity of the diversion. Seed and mulch any bare areas that develop
- Easements should be obtained to ensure the diversion is maintained as constructed

References

Additional guidance for evaluation, planning, and design of diversions is given in:

- NRCS Ohio Practice Standard 362, Diversion.
- NRCS Engineering Field Handbook (EFH) Part 650, Chapter 9 - Diversion
- Agricultural Handbook 667, Stability Design of Grass-lined Open Channels.

Specifications
for
Diversion



1. All trees, brush, stumps, and other unsuitable material shall be removed from the work site.
2. The diversion shall be excavated and shaped to the proper grade and cross section.
3. Fill material used in the construction of the channel shall be well compacted in uniform layers not exceeding 9 inches using the wheel treads or tracks of the construction equipment to prevent unequal settlement.
4. Excess earth shall be graded or disposed of so that it will not restrict flow to the channel or interfere with its functioning.
5. Fertilizing, seeding, and mulching shall conform to the recommendations in the applicable vegetative specifications.
6. Construction shall be sequenced so that the newly constructed channel is stabilized prior to becoming operational. To aid in the establishment of vegetation, surface water may be prevented from entering the newly constructed channel through the establishment period.
7. Gullies that may form in the channel or other erosion damage that occurs before the grass lining becomes established shall be repaired without delay.

4.6 Terrace

Description

A terrace is an earthen embankment, channel, or a combination ridge and channel constructed across the slope to:

- reduce slope length
- reduce erosion
- improve, intercept, and conduct surface runoff at a nonerosive velocity to a stable outlet
- reform the land surface
- prevent gully development
- reduce flooding

Conditions Where Practice Applies

This practice is applicable where:

- reduced slope length is needed to control erosion from concentrated runoff
- runoff and sediment can damage land or improvements downstream
- the soils and topography are such that terraces can be constructed with reasonable effort
- a suitable outlet can be provided

Planning Considerations

Terraces should generally fit the contour of the land. A system of terraces down the slope will work best if they are aligned parallel to each other. Land grading or benching between the terraces can enhance or improve the topography. On steeper slopes, by borrowing fill material above or below the terrace to construct the ridge, terraces can help to flatten the land between the terraces. Proper planning of the layout of a terrace system will aid in balancing cuts and fills.

Water Quality

Besides the primary design objective of reducing slope length and reduce erosion, water quality benefits may also be achieved. Terraces may promote settling and infiltration. Modifications may be made that store the water quality volume by adding weirs or check dams in order to detain and treat runoff for a minimum of 24 hours. See Water Quality Ponds for an explanation of the water quality volume.

Location

Locations of terraces shall be determined by topography, outlet conditions, land use, soil type, and length of slope. When terraces are used to intercept subsurface flow or seepage, depth and location of seepage should be used to determine location and spacing of terraces.

A subsurface drain should be used as necessary to establish and maintain vegetative cover.

Design Criteria

Runoff

Runoff computation will be based upon the most severe soil and cover conditions that will exist in the area draining into each terrace during the planned life of the structure. Use the NRCS Technical Release 55 (TR 55) or other suitable method shall be used to determine peak rate of runoff.

Capacity

Terraces shall have a capacity to carry the peak rate of runoff from a 10-yr. frequency storm for the area draining into each terrace. Where high-hazard conditions exist, higher frequency storms should be chosen to provide protection compatible with conditions. Terraces designed to protect urban areas, buildings and roads, shall have a capacity to carry the peak rate of runoff from a 25-yr. frequency storm with a freeboard of not less than 0.3 feet.

Types of Terraces

There are 2 types of terraces. Steep slope terraces are constructed with steeper ridges and are generally more suitable for steeper topography (See Figure 1). Broad based terraces are constructed with flatter ridges and are generally more suitable for flatter topography (See Figure 4.6.1).

Spacing

A system of terraces, whether steep sloped or broad based, shall be spaced not less than 90-ft. apart, or exceed the following:

Table 4.6.1

Land Slope-(Percent)	Terrace Spacing-(Feet)
0-2	500
2-4	400
4-6	400
6-9	300
9-12	250

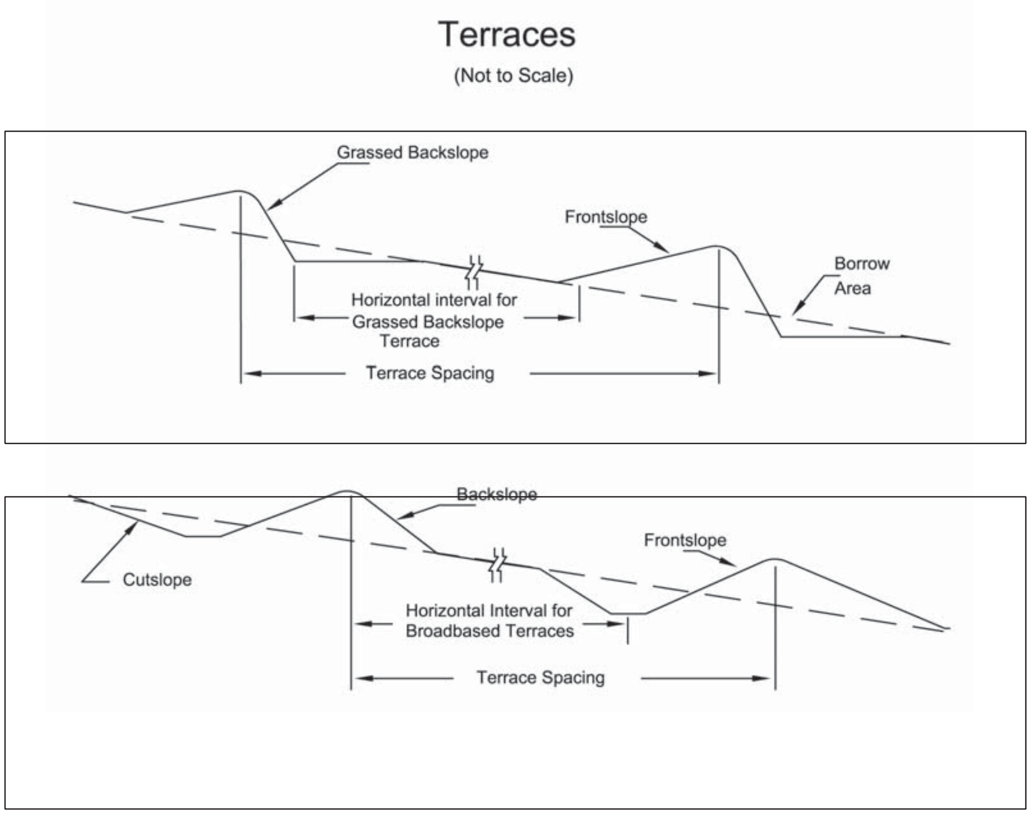


Figure 4.6.1

Cross Section

The channel shall be parabolic or trapezoidal. The terrace shall be designed to have stable side slopes. The maximum side slope shall be 2 horizontal to 1 vertical. The ridge height shall include a minimum of 0.3 ft of freeboard and a minimum settlement factor of 10% in addition to the design flow depth. The ridge shall have a minimum constructed top width of 4 feet at the design elevation. The minimum cross sectional area shall meet the specified dimensions. The top of the constructed ridge shall not be lower at any point than the design elevation plus the specified amount for settlement. Risers will be used on underground outlets (Figure 4.6.2). The riser will be placed in the lowest area so that all the water will drain from the terrace.

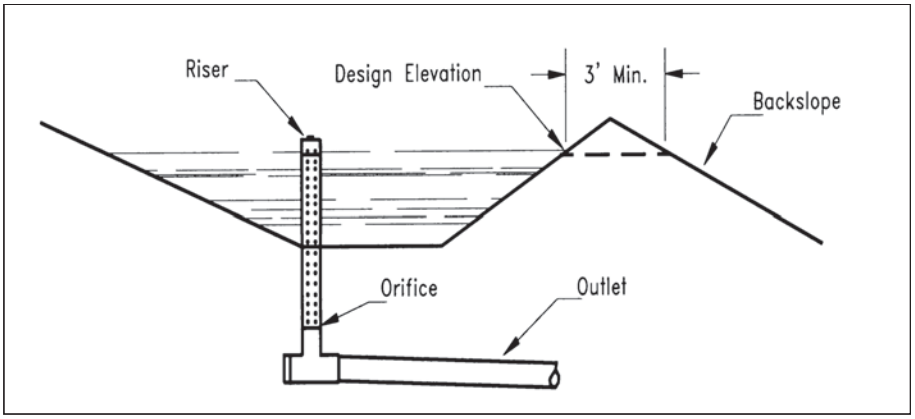


Figure 4.6.2 Riser utilized to drain terrace.

It is necessary to select the type of terrace before layout as the cross section affects terrace spacing. Cuts and fills should be made in such a manner that topography would be enhanced. Where deep cuts will expose unfavorable subsoil, the topsoil will be stripped, stockpiled and replaced. Terraces can be constructed having flatter broad base backslope or a steeper 2 horizontal to 1 vertical backslope.

The broad base terrace is constructed with flatter side slopes, and borrow is usually taken from the uphill side of the ridge. The broad base terrace is generally adapted to land slopes of less than 6 percent.

The steep slope terrace is constructed with steep side slopes (no steeper tan 2 to 1) that must be maintained in sod. Steep slope terraces are best adapted to field slopes to 6 percent or greater. Borrow is normally taken from the downhill side where the slope of the land between the terraces is reduced.

Grade

Channel grades are generally 2% or less to reduce velocities. Grade shall be as uniform as possible.

Design Velocity of Vegetative Lining:

Terraces shall be designed so that the velocity of flow expected from a 10-year frequency storm does not exceed the permissible velocity for the type of lining used (see the table below). Manning's Equation or other suitable method should be used to determine design velocity.

Table 4.6.2 Grass Lining Maximum Flow Velocity for a 10-Yr. Frequency Storm

Soil		Maximum Velocity (fps)		
Texture	**Type**	**Seed & mulch**	**Seed & Matting**	**Sod**
Sand, Silt, Sandy Loam, Silt Loam	Sand	1.5	3.0	3.5
Silty Clay Loam, Sandy Clay Loam	Firm Loam	2.0	4.0	4.0
Clay	Clay	2.5	40	5.0
N/A	Gravel	3.5	5.0	6.0
N/A	Weathering Shale	4.5	5.0	N/A

Note: Soil texture/type can be determined from the soil surveys. If the channel is on fill, the soil should be tested.

Outlets

All terraces shall have a stable outlet.   Outlets for terraces may be surface outlets such as grassed waterways or rock lined channel, or an underground outlet such as pipe.

- *Surface outlet.* A grassed waterway or vegetated area. may be suitable as a terrace outlet if the waterway will convey runoff water to a point where the outflow will not cause damage. The outlet must be stable and vegetated prior to construction of the terrace. In cases where the terrace outlets into a larger ditch or stream with a continual or seasonal base flow, protection of that portion of the terrace affected by this wet condition is necessary. This may be accomplished by installation of use of a rock lined outlet or grade stabilization structure (see Rock Lined Channel / Rock Outlet Protection).
- *Underground outlet.* Underground outlets may be used on flat, or nearly flat, terraces. The outlet consists of an inlet or riser and underground conduit. An orifice plate, decrease in conduit size or other features shall be installed in each inlet as needed to control the release rate and prevent excessive pressure when more than one terrace discharges into the same conduit. The discharge, when combined with the storage within the terrace, is to be such that a 10-year frequency, 24-hour storm will not overtop the terrace. The release time shall not exceed 24 hours for the design storm.

Conduits must be installed deep enough to prevent damage from traffic on roads that cross the conduit. The inlet is to consist of a vertical perforated pipe of a material suitable for the intended purpose.

All risers (except the top one) shall be placed on a lateral leading to the main line so that in event the riser is damaged the main will not be disturbed and can continue to outlet other terraces.

A 6-in. diameter riser will have as minimum 4 rows of slots 0.75 in. x 4 in. in size or 24 holes of 0.75 in. diameter per lineal foot of riser. An 8-in. diameter riser should have 6 rows of slots. Care will be taken not to cut the seam in helical pipe, as this will allow it to unwind. The riser shall extend above the ground a minimum of 3 ft. for good visibility and within 6 in. of the terrace top of terraces have a fill height of 3.5 ft. or higher.

Establishing Vegetation

All terraces shall be vegetated or otherwise stabilized, as soon as possible after construction. Stabilization should be done according to the appropriate Standards and Specifications for Vegetative Practices (e.g. Permanent Seeding, Mulching, TRECP).

- *For design velocities of less than 3.5 fps,* seeding and mulching may be used for the establishment of the desired vegetation. Mulch netting should be used to protect the seeding during establishment. It is recommended that when conditions permit, a temporary diversion or other means be used to prevent water from entering the terrace during the establishment of vegetation.
- *For design velocities of more than 3.5 fps,* the terrace shall be stabilized with seeding protected by erosion control matting or blankets, or with sod. It is recommended that when conditions permit, a temporary diversion or other means be used to prevent water from entering the terrace during the establishment of vegetation.

Sedimentation

Terraces should not be used below high sediment producing areas unless land treatment practices or structural measures that will prevent damage to the terrace are designed and installed prior to installation of the terrace. If some accumulation of sediment cannot be prevented, then the design shall include extra capacity for the sediment. Accumulation of sediment shall be considered in the maintenance plan for this practice.

Maintenance

A maintenance program shall be established to maintain capacity, vegetative cover, and associated structural components such as inlets, outlets, and subsurface drains. Items to consider in the maintenance program include:

- Determine responsible party to inspect and maintain the terraces after construction
- Protect the terraces from damage by equipment and traffic
- Fertilize annually to and maintain a vigorous stand of grass
- Mow the terraces regularly to maintain a healthy and vigorous stand of grass
- Inspect terraces regularly, especially following heavy rains
- Repair damage to terraces immediately. Damaged areas will be filled, compacted, and seeded immediately. All broken subsurface drains should be repaired
- Remove sediment deposits to maintain capacity of terraces. Seed and mulch any bare areas that develop
- Easements should be obtained to ensure the terraces are maintained as constructed

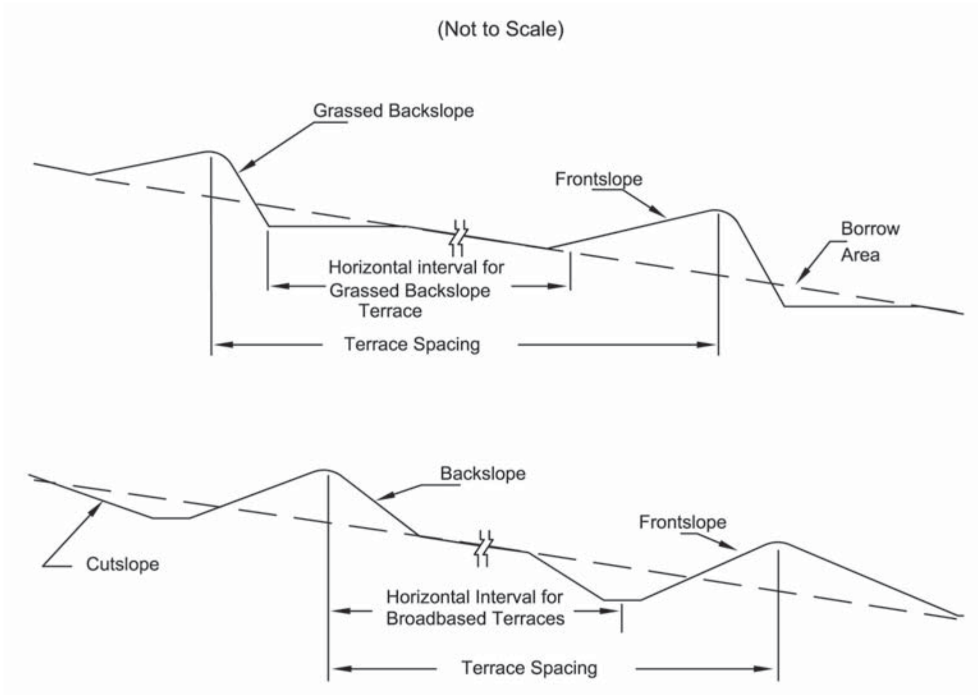
References

Additional guidance for evaluation, planning, and design of terraces is given in:

- NRCS Ohio Practice Standard 600, Terrace.
- NRCS Engineering Field Handbook (EFH) Part 650, Chapter 8 - Terraces.

Specifications
for

Terraces



1. All ditches or gullies shall be filled before constructing the terrace or shall be part of the construction. All old terraces, fence rows, organic matter, hedgerows, trees, and other obstructions shall be removed, as necessary.
2. The terraces shall be constructed to planned alignment, grade, and cross section with the specified overfill for settlement, and the channel shall be graded to drain reasonably well.
3. Fill material shall be free of sod, roots, organic material, stones larger than 6 in. (.15 m) or other objectionable material.
4. Fill will be placed in approximately horizontal lifts no greater than 6-in thick prior to compaction. Each lift will be compacted using excavating equipment, or other equipment that will obtain equivalent compactive effort. At least two passes (tread tracks) of the compacting equipment will be required completely covering each lift. Fill material will have a moisture content that will allow a ball of soil to hold together when squeezed by hand.
5. Any ditch or depression at the bottom of the back slope shall be filled and smoothed so that drainage will be away from the terrace and not parallel to it.
6. Provisions must be made to prevent piping if underground conduits are located under terrace ridges. Mechanical compaction of trench backfill will be required for sections of underground outlet pipes located beneath terrace, channels, and ridges. The materials used for the inlet and conduit shall be as specified on the plan. Terrace ridges constructed across gullies or depressions shall be compacted by machinery travel or by other suitable means to ensure proper functioning of the terrace. The surface of the finished terrace shall be reasonably smooth and present a workmanlike finish.
7. When specified on the plan, topsoil shall be stockpiled and spread over excavations and other areas to facilitate restoration of productivity.
8. Fertilizing, seeding, and mulching shall conform to the recommendations in the applicable vegetative specification.

4.7 Subsurface Drain

Description

Subsurface drainage is the installation of a conduit, such as corrugated plastic tubing, tile, or pipe installed beneath the ground surface to collect and/or convey drainage water. The purpose of subsurface drainage is to:

- Provide internal drainage of slopes to improve slope stability and reduce erosion
- Intercept and reroute existing subsurface drains and drainage systems
- Regulate the water table and ground water flows, and relieve artesian pressures
- Intercept and preventing water movement into a wet area
- Remove surface runoff, or standing water
- Provide internal drainage behind bulkheads, retaining walls, etc
- Collect ground water for beneficial uses
- Remove water from heavy use areas, such as around buildings, roads, and other structures
- Regulate water to control health hazards caused by pests such as flies, or mosquitoes

Conditions Where Practice Applies

Subsurface drains are used in areas having a high water table where benefits of lowering or controlling ground water or surface runoff justify the installation of such a system. All lands to be drained shall be suitable for the intended use after installation of required drainage and other practices. The soil shall have enough depth and permeability to permit installation of an effective and economically feasible system.

An outlet for the drainage system shall be available, either by gravity flow or by pumping. The outlet shall be adequate for the quantity and quality of effluent to be disposed of with consideration of possible damages above or below the point of discharge that might involve legal actions. Ohio drainage and water laws shall be adhered to in the planning and installation of drains.

Design Criteria

Subsurface drainage shall be designed by acceptable engineering methods such as those outlined in Chapter 14 – Water Management (Drainage) of the NRCS Part 650 Engineering Field Handbook, or the following:

Required Capacity of Subsurface Drains

Where the land to be drained has adequate surface drainage, either natural or artificial, the spacing between drains and their capacity shall be based on minimum removal rates as follows:

Table 4.7.1

Soil	Inches to be Removed in 24 Hours
Mineral	1/2
Organic	3/4

Where it is necessary to admit surface water to the subsurface drain system through surface inlets:

Table 4.7.2

Soil	Inches to be Removed in 24 Hours	
	Blind/Inlets	Open Inlets
Mineral	3/4	1
Organic	1	1-1/2

Required Capacity of Interceptor Subsurface Drains

Where springs or seepage are to be intercepted, the subsurface drain size will be determined on the basis of the estimated flow, or computed as outlined in Chapter 14 – Water Management (Drainage) of the NRCS Part 650 Engineering Field Handbook or the following table.

Table 4.7.3

Interceptor, Random, and Single Drain Line Inflow Rates				
Soil Texture	Inflow Rate per 1,000 feet of line (cfs)			
	Land Slope			
	0-2%	2-5%	5-12%	> 12%
Coarse Sand and Gravel	1.0	1.1	1.2	1.3
Sand	0.50	0.55	0.60	0.65
Sandy Loam	0.25	0.28	0.30	0.33
Silt Loam	0.10	0.11	0.12	0.13
Clay and Clay Loam	0.20	0.22	0.24	0.26

Size of Subsurface Drain

The size of drains shall be computed by applying Manning's Formula. The size shall be based on the required capacity and computed using one of the following:

1. Hydraulic grade line parallel to the bottom grade of the subsurface drain with the conduit flowing full at design flow.
2. The conduit flowing part full where a steep grade or other condition requires excess capacity.
3. Conduit flowing under pressure with hydraulic grade line set by site conditions on a grade that differs from that of the subsurface drain. This procedure shall be used only where surface water inlets or nearness of the drain to outlets with fixed water elevations permit satisfactory estimates of hydraulic pressure and flows under design conditions.

The outlet pipe is part of the hydraulic system, and its grade and roughness characteristic ("n" value) must be considered in determining the required size of the outlet pipe.

All subsurface drains shall have a nominal diameter that equals or exceeds 3".

Existing Subsurface Drains and Drainage Systems

Care should be taken to thoroughly evaluate existing subsurface drains and drainage systems that might be impacted. This evaluation should be based on adequate surveys, field investigations, and a check of existing records, or as-builts, that might be available on the system. When adding on to an existing system, the capacity of the existing drain line must be known, or should be calculated, so as to not overload and damage the existing drain. The existing drain line must be in good condition before a decision is made to add more lines to it. When eliminating the downstream end of an existing drainage system, a new drain line must be provided as an outlet. This new re-routed drain line must have adequate capacity to handle all the remaining upstream drain lines.

Depth, Spacing, and Location

The depth, spacing and location of the subsurface drain shall be based on site conditions, including soils, topography, ground water conditions, land use, and outlets. In general, however, a depth of 3 feet and a spacing of 50 feet will be adequate.

The minimum depth of cover over subsurface drains in mineral soils shall be 2 ft, and may exclude sections of line near the outlet, or sections lain through minor depressions that will be filled as part of the installation. (After filling these minor depressions, the depth of cover over the drain will be at least 2 ft.

Minimum Velocity and Grade

In areas with no sedimentation hazard, the minimum grades shall be based on site conditions and a velocity of not less than 0.5 ft/s. Where it is determined that a sedimentation hazard exists, a velocity of not less than 1.4 ft./s shall be used to establish the minimum grades if site conditions permit. Otherwise, provisions shall be made for prevention of sedimentation by use of filters or collection and periodic removal of sediment by use of sediment traps or the periodic cleaning of the lines by high pressure jetting systems or cleaning solutions as specified in the plans.

Maximum Grade and Protection

On sites where topographic conditions require the use of subsurface drain lines on steep grades and design velocities will be greater than indicated in the following table, special measures shall be used to protect the conduit.

Table 4.7.4 Maximum Permissible Velocity in Drains Without Protective Measures

Soil Texture	Velocity (ft/s)
Sand and Sandy Loam	3.5
Silt and Silt Loam	5.0
Silty Clay Loam	6.0
Clay and Clay Loam	7.0
Coarse Sand or Gravel	9.0

Protective measures shall be specified for each job based on the particular conditions of the job site. These measures shall include one or more of the following:

1. Use only drains that are uniform in size and shape and with square ends to obtain tight fitting joints. Lay the drains so as to secure a tight fit with the inside diameter of one section matching that of the adjoining sections.
2. Wrap open joints with tar impregnated paper, burlap, or special fabric type filter material.
3. Place the conduit in a sand and gravel envelope or blinding with the least erodible soil available.
4. Seal joints or use a watertight pipe or nonperforated continuous tubing.
5. For continuous pipe or tubing with perforations, completely enclose the pipe with geotextile type filter material, or well-graded sand and gravel.
6. Install open risers for air release or entry.

Iron Ochre Considerations

If drains are to be installed in sites where iron ochre problems are likely to occur, provisions should be made to provide access for cleaning the lines. Each drain line should outlet directly into an open ditch and/or should have entry ports as needed to provide access for cleaning equipment. Drain cleaning provisions should be installed in such a way that the drains can be cleaned in an upstream or rising grade direction. If possible, drains in ochre-prone areas should be installed during the dry season when the water table is low and the iron is in its insoluble form.

Where possible, in areas where the potential for ochre problems is high, some protection against ochre development can be provided by designing an outlet facility to ensure permanent submergence of the drain line.

Protection Against Root Clogging

Problems may occur where it is necessary to place drains in close proximity to perennial vegetation. Roots of water-loving trees, such as willow, cottonwood, elm and soft maple, or some shrubs and grasses growing near subsurface drains may enter and obstruct the flow.

The first consideration is to use non-perforated tubing or closed joints through the root zone area. Where this is not possible, water-loving trees must be removed from a distance of at least 100 feet on each side of the drain. A distance of 50 feet must be maintained from other species of trees except for fruit trees. Drains located close to the fruit trees can often drain orchards.

Where grasses may cause trouble on drain lines, facilities may be installed to provide a means for submerging the line to terminate the root growth as desired or to maintain a water table above the drain lines to prevent growth into the system.

Materials

Subsurface drains include conduits of clay, concrete, metal, plastic, or other materials of acceptable quality. The conduit shall meet strength and durability requirements of the site. All conduits shall meet or exceed the minimum requirements specified in the Material Specification.

Foundation Requirements

When soft or yielding foundations are encountered, they shall be stabilized and the lines shall be protected from settlement by adding gravel or other suitable materials to the trench, by placing the conduit on treated plank that will not readily decompose, or other rigid supports, or by using long sections of perforated or watertight pipe with adequate strength to ensure satisfactory subsurface drain performance. The use of flat treated plank is not recommended for corrugated plastic tubing. If planking is used on CPT, it should be constructed with a "v" groove or other means to provide the required support to the side walls of the conduit.

Loading

The allowable loads on subsurface drain conduits shall be based on the bedding conditions and the crushing strength of the kind and class of drain specified for the job.

The design load on the conduit will be based on a combination of equipment loads and trench loads.

1. Equipment loads are based on the heaviest wheel loads of the construction equipment or other vehicles being used, or likely to be used, in the area where the subsurface drainage system will be installed, the maximum height of cover over the conduit, and the trench width. Equipment loads on the conduit decrease as the depth of cover increases and may be neglected when the depth of cover exceeds 6 feet.
2. Trench loads are based on the type of backfill, the height of backfill over the conduit, the width of trench, and the unit of weight of the backfill material. A factor of safety of not less than 1.5 shall be used in computing the design trench load.

Heavy-duty corrugated plastic drainage tubing shall be specified if the soil is rocky, if cover over the tubing is expected to exceed 10 ft., or trench widths are expected to exceed 2 ft. (This refers to trench widths in the area of the tubing and at least 1-foot above the top of the tubing.)

Filters and Filter Materials

Filters will be used around conduits, as needed, to prevent movement of the surrounding soil material into the conduit. The characteristics of the surrounding soil material, site conditions and the velocity of flow in the conduit will determine the need for a filter. A suitable filter should be specified if:

1. Local experience indicates a need,
2. Soil materials surrounding the conduit are dispersed clays, low plasticity silts, or fine sands (ML or SM with P.I. less than 7),
3. Where deep soil cracking is expected, or
4. Where the method of installation may result in voids between the conduit and backfill material.

If a sand-gravel filter is specified, it shall be clean, hard, durable material. The filter gradation will be based on the gradation of the base material surrounding the conduit within the following limits:

- D_{15} size smaller than 7 times d85 size but not smaller than 0.6 mm,
- D_{15} size larger than 4 times d_{15} size.
- Less than 5 percent passing No. 200 sieve,
- Maximum size smaller than 1.5 inches,

Where D represents the filter material and d represents the surrounding base material. The number following each letter is the percent of the sample, by weight that is finer than that size. For example, D15 size means that 15 percent of the filter material is finer than that size.

Specified filter material must completely encase the conduit so that all openings are covered with at least 3 inches of filter material.

Artificial fabric or mat-type filter materials may be used, provided that the effective opening size, strength, durability, and permeability are adequate to constantly filter the soil to protect subsurface drain operation throughout the expected life of the system. (These filters should not be used under submerged conditions or where sediment laden flows occur prior to backfill.) Artificial fabric or mat-type filters should not be used in silty soil conditions.

Envelopes and Envelope Material

Envelopes shall be used around subsurface drains where required for proper bedding of the conduit, or where necessary to improve the characteristics of flow of ground water into the conduit.

Envelope materials shall consist of sand-gravel material. Sand-gravel envelope materials shall all pass a 1.5 inch sieve; not more than 30 percent shall pass a No. 60 sieve; and not more than 5 percent shall pass the No. 200 sieve. ASTM-C-33 fine aggregate for concrete has been satisfactorily used and is readily available.

Placement and Bedding

The trench bottom shall be smooth and free of clods and loose or exposed rock. All subsurface drains, whether flexible conduit such as plastic, or rigid conduit such as clay and concrete, shall be laid to a neat line and grade. For trench installations of corrugated plastic tubing 8 inches or less in diameter, one of the following methods will be specified:

1. A shaped groove or 90 degree V-notch in the bottom of the trench for tubing support and alignment
2. A sand-gravel envelope, at least 3 inches thick, to provide support
3. Compacted soil bedding material beside and to 3 inches above the tubing

For trench installations of corrugated plastic tubing larger than 8 inches in diameter, the same bedding requirement will be met except that a semi-circular or trapezoidal groove shaped to fit the conduit will be used rather than the V-shaped groove.

Rigid drainage conduits, such as clay or concrete drain tile, do not need the 90 degree V-groove in the trench bottom, however, the trench bottom must be shaped so that good alignment in the center of the trench is assured.

Where the conduit will be bedded with fine-grained friable soil or a sand and gravel mixture, the minimum trench width will be at least 0.5 ft. greater than the outside diameter of the conduit. When the conduit is installed in conditions where cloddy material will likely be used for bedding, the trench width will be at least 1.0 ft. greater than the outside diameter of the conduit. In all cases the conduit will be laid in the center of the trench. When the conduit must be installed in rocky conditions, the trench must be over excavated and backfilled to grade with a suitable bedding materials.

All trench installations should be made when the soil profile is in its driest possible conditions in order to minimize problems of trench stability, conduit alignment, and soil movement into the drain.

For trench installations where a sand-gravel or compacted bedding is not specified, the conduit will be blinded with selected material containing no hard objects larger than 1.5 inches in diameter, and will be carried to a minimum of three inches above the conduit.

Conduit Perforations Special Requirements:

Where perforated conduit is required, the water inlet area shall be at least 1 inch2/ foot of conduit length. Round perforations shall not exceed 3/16-inch diameter except where filters, envelopes, or other protection is provided or for organic soils, where a maximum hole diameter of _ inch may be used. Slotted perforations shall not exceed 1/8 inch in width.

Outlets

Subsurface drain outlets shall be protected against erosion from undermining of the conduit, against entry of tree roots, against damaging periods of submergence, and against entry of rodents or other animals into the subsurface drain.

The vertical interval between the bottom of the outlet pipe and the ditch bottom shall be at least 1.0 ft. except that this vertical interval may be reduced to 0.5 ft. if (1) the outlet ditch is not subject to any significant deposition of sediment, or if (2) there is an effective maintenance program on the outlet ditch. In all cases, the subsurface drain shall outlet above the normal low flow elevation in the outlet ditch. Where the subsurface drain outlets into Lake Erie or its backwater, the invert of the conduit shall be no lower than 573.0 MSL.

When discharging a subsurface drainage system into a pond or lake, the minimum elevation of the outlet pipe invert shall be at the normal level of the pond or lake. When the outlet is located near an area of sediment deposition along the shoreline, the minimum elevation of the invert shall be at least 1.0 foot above the normal water elevation.

Where no surface water enters the ditch at the location of the subsurface drain outlet, a continuous section of pipe without joints or perforations shall be used. The outlet pipe and its installation shall conform to the following requirements:

1. Due to the hazard from burning of vegetation on the ditch bank the material from which the outlet pipe is fabricated shall be fire resistant. Where the hazard of burning is high, the outlet pipe shall be fireproof. PVC pipe is fire resistant, and pipe meeting ASTM-D 2241, ASTM-D-3034, or better have adequate strength to be used for outlet pipes.
2. At least two-thirds of the pipe shall be buried in the ditch bank and cantilevered section shall extend to or beyond the toe of the ditch side slope, or the side slope shall be protected from erosion. The minimum length of pipe shall be 8 ft. for diameters 8” or less; 12 ft. for 10” and 12” diameters; 16’ for 15” and 18” diameters, and 20 ft. for diameters larger than 18”.

3. Where ice or floating debris may damage the outlet pipe, the outlet shall be recessed to the extent that the cantilevered portion of the pipe will be protected from the current in the ditch.
4. Headwalls, which are used for subsurface drain outlets, shall be adequate in strength and design to avoid washouts and other failures.
5. Adverse visual impact of projecting outlets will be minimized.

Where surface water enters the ditch at the location on the drain outlet a grade stabilization structure shall be used.

Auxiliary Structures and Protection

Watertight conduits strong enough to withstand the expected loads shall be used where subsurface drains cross under irrigation canals, grassed waterways, or other ditches. Conduits under roadways shall be designed to withstand the expected loads. Shallow drains through depression areas and near outlets shall be protected against hazards of vehicular equipment, and freezing and thawing.

Structures installed in drain lines must not unduly impede the flow of water in the system. Their capacity shall be no less than that of the line or lines feeding into or through them. The use of internal couplers for corrugated plastic tubing will be allowed.

If the drain system is to carry surface water flow, surface water inlets shall have a capacity of no greater than that required providing the maximum design flow in the drain line or lines.

Junction boxes, manholes, catch basins, and sand traps shall be accessible for maintenance. A clear opening of not less than 2 ft. shall be provided in either circular or rectangular structures.

The size of breathers and relief wells is generally based on the available materials rather than on hydraulic considerations, and shall not be less than 4 inches in diameter.

The drain system shall be protected against velocities exceeding those provided under "Maximum Permissible Velocity without Protective Measures" and against turbulence created near outlets, surface inlets, or similar structures. Continuous or closed-joint pipe, or non-perforated tubing shall be used in drain lines adjoining the structures where excessive velocities will occur.

Junction boxes shall be installed if more than three main drains join or if two main drains join at different elevations. In some cases it may be possible to bury junction boxes. Then a solid, durable cover will be used and there must be at least 18 inches of natural soil cover over the cover.

If surface water is to be admitted to subsurface drains, inlets shall be designed to exclude debris and prevent sediment from entering the conduit. Surface water inlets will be offset from main lines unless located at the upper end of the line.

Lines flowing under pressure shall be designed to withstand the resulting pressures and velocity of flow. Auxiliary surface waterways shall be used where feasible.

If not connected to a structure, the upper end of each subsurface drain line shall be capped with a tight-fitting cap of the same material as the conduit or other durable materials.

Early Use Damage

Newly installed drains at shallow depths (less than 3') and without a gravel envelope may be crushed, especially after a heavy rain, by heavy equipment traveling over the freshly backfilled trenches. Heavy equipment should avoid crossing drain lines, especially mains and sub-mains.

Operation and Maintenance

A properly designed and installed subsurface drain requires little maintenance. However, inlets, outlets, and drain lines should be periodically inspected. A maintenance plan should include the following items:

- Determine responsible party to inspect and maintain the practice after construction
- Protect the drain from damage by equipment, traffic, or livestock
- Check the drains periodically to verify that the drains are operating properly.
- Investigate wet areas along the drain line for blockage by roots, drain separation, or other problems. Repair damage promptly.
- Keep the outlet free of sediment and debris
- Keep the animal guard in place and functional

References

Additional guidance for evaluation, planning, and design of subsurface drainage is given in:

- NRCS Ohio Practice Standard 606, Subsurface Drain.
- NRCS Engineering Field Handbook (EFH) Part 650, Chapter 14 - Water Management (Drainage)
- Illinois Urban Manual: A Technical Manual Designed for Urban Ecosystem Protection and Enhancement, prepared for the Illinois EPA by Illinois NRCS

Materials for Subsurface Drains

The following specifications pertain to products currently acceptable for use as subsurface drains. These specifications are also to be applied in determining the quality of materials referenced by other standards:

Table 4.7.5 Subsurface Drain Materials

Type	Specification
Plastic	
Corrugated polyethylene (PE) tubing and fittings 3-6 in.	ASTM-F-405[1]
Corrugated polyethylene (PE) tubing and fittings 8-24 in.	ASTM-F-667[1]
Corrugated polyvinyl chloride (PVC) tubing and Compatible fittings	ASTM-F-800[1]
Polyvinyl chloride (PVC) corrugated sewer pipe with a smooth Interior and fittings 4-8 in.	ASTM-F-949[1] or D-3034 type
Polyvinyl chloride (PVC) pipe	PSM or PSP
Clay	
Clay drain tile	ASTM-C-4[1]
Clay drain tile, perforated	ASTM-C-498[1]
Clay pipe, perforated, standard and extra strength	ASTM-C-700[1]
Clay pipe, testing	ASTM-C-301[1]
Concrete	
Concrete drain tile	ASTM-C-412[1]
Concrete pipe for irrigation or drainage	ASTM-C-118[1]
Concrete pipe or tile, determining physical properties of	ASTM-C-497[1]
Concrete sewer, storm drain, and culvert pipe	ASTM-C-14[1]
Reinforced concrete culvert, storm drain, and sewer pipe	ASTM-C-76[1]
Perforated concrete pipe	ASTM-C-444[1]
Portland cement	ASTM-C-150[1]
Other	
Styrene rubber plastic drain pipe and fittings	ASTM-D-2852[1]
Pipe, corrugated (aluminum alloy)	Federal Spec. (WW-P-4022)
Pipe, corrugated (aluminum alloy)	Federal Spec. (WW-P-4052)

[1] Specifications can be obtained from the American Society for Testing and Materials, 1016 Race Street, Philadelphia, PA 19103

[2] Specifications can be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

Specifications
for
Subsurface Drain

1. Safety – All operations shall be carried out in a safe manner and meet applicable health and safety regulations. Workers should not enter a vertical trench deeper than 5 feet unless the trench walls are supported by shoring or by a trench shield. In lieu of shoring on trenches greater than 5 feet in depth, the walls above the 5 foot level may be sloped to a stable slope, no steeper than 1-1/2:1

2. Trenching – Trenching width shall be adequate for proper installation of the conduit; must allow proper joining of sections; and must allow proper placement of filter, envelope, or blinding materials. The trench bottom shall be constructed to proper grade and shape before placement of the conduit.

- For clay and concrete tile, the trench width will be a minimum of 3 to 6 inches on both sides of tubing. A groove must be formed in the bottom of the trench that is adequate to hold the tile in alignment during placement and backfilling.
- Where rock is encountered the trench will be over excavated a minimum of 6 inches and refilled to proper grade with a suitable bedding material.
- Where rock is encountered the trench will be over excavated a minimum of 6 inches and refilled to proper grade with a suitable bedding material.

3. Bedding – The trench bottom shall be smooth and free of clods or loose and exposed rock. Where a gravel envelop is not specified, the bottom of the trench shall be shaped to conform to the pipe. If unstable soils are encountered, the trench bottom must be stabilized before placement of conduit. Where necessary, the unstable material will be removed and replaced with sand-gravel or similar suitable stabilizing material of sufficient thickness and gradation to prevent soil movement into the tile.

4. Backfilling – Place backfill material so that displacement or deflection of the conduit will not occur. This is preferably on an angle, so the material flows down the front slope. Avoid large stones, frozen material, and dry clods that cause concentrated point loads on the tubing or damage the conduit. The trench should be backfilled as soon as practical. When installing the tubing on a hot day, backfilling should be delayed until tubing temperature cools to the soil temperature.

5. Inspecting and Handling Materials – Material for subsurface drains shall be carefully inspected before the drains are installed. Plastic pipe and tubing shall be protected from hazard causing deformation or warping. Plastic pipe and tubing with physical imperfections shall not be installed. A damaged section shall be removed and a suitable joint made connecting the retained sections. Clay and concrete tile shall be checked for damage from freezing and thawing before it is installed. All material shall be satisfactory for its intended use and shall meet applicable specifications and requirements.

SPECIFICATIONS FOR FLEXIBLE CONDUIT

General Requirements

All conduits shall be laid to line and grade in such a way that the side walls are continuously and uniformly supported with suitable bedding material. Such material shall be properly placed and compacted to provide lateral restraint against deflection and to protect the conduit against collapse during backfilling.

Plow Installation

Plow installation has been satisfactorily used in many situations. Special care needs to be exercised relative to grade control and bedding conditions.

Placement

Flexible conduit will be placed in such a way that maximum stretch does not exceed 5 percent.

Fittings shall be installed in accordance with instructions furnished by the manufacturers. Couplers are required at all joints and fittings, at all changes in direction (where the center-line radius is less than three times tubing diameter), at changes in diameter, and a junction with another line.

Caps are needed at the ends of lines. All fittings shall be compatible with the tubing. Place selected bedding material, containing no hard objects larger than 11/2 inches in diameter in the trench to a minimum depth of 6 inches over the conduit. The conduit will be held in place mechanically until secured by blinding.

SPECIFICATIONS FOR CLAY AND CONCRETE TILE

The use of concrete tile in acid and sulfate soils shall be in accordance with the following limitations:

Table 4.7.6 Limitations of acid and sulfate soils.

Acid Soils:

		Lower Permissible Limits of pH Values	
		Organic and Sandy Soils	Medium and Heavy-Textured Soils
Class of Tile			
ASTM-C-412			
	Standard quality	6.5	6.0
	Extra quality	6.0	5.5
	Heavy duty extra quality	6.0	5.5
	Special quality	5.5	5.0
ASTM-C-14			
	C-118, C-444	5.5	5.0

Note: Figures represent the lowest reading of pH values for soil or soil water at subsurface drain depth.

Sulfate Soils:

Type of Tile and Cement (minimum)		Permissible Maximum limit of sulfates singly or in combination (p/m)
Tile:	ASTM-C-412	
	Special quality	7,000
	C-14, C-118, C-444	
Cement:	ASTM-C-150, Type V	
Tile:	ASTM-C-412	
	Extra quality	3,000
	Heavy-duty extra quality	
	C-14, C-118, C-444	
Cement:	ASTM-C-150, Type II or V	
Tile:	ASTM-C-412	
	Standard quality	1,000
	C-14, C-118, C-444	
Cement:	ASTM-C-150, any type	

Note: Figures represent the highest reading of sulfates for soil or soil water at subsurface drain depth.

Bell and spigot, tongue and groove, and other types of tile that meet the strength, absorption, and other requirements of clay or concrete tile as specified in the preceding paragraphs, except for minor imperfections in the bell, the spigot tongue or the groove, and ordinarily classes by the industry as "seconds," may be used for drainage conduits, provided that the pipe is otherwise adequate for the job.

Placement

All conduits shall be laid to line and grade and covered with the specified blinding, envelope, or filter material to a depth of not less than 3 inches around the drain. Blinding material shall contain no hard objects larger than 1-_ inches in diameter.

When a sand-gravel filter is specified, all openings in the conduit must be covered with at least 3 inches of filter material except that the top of the conduit and the side filter material may be covered with a sheet of plastic or similar impervious material. The impervious sheet will be covered with at least 3 inches of blinding material.

Joints between the drain tile shall not exceed 1/8 inch, except in organic soils where some of the more fibrous types make it desirable to increase slightly the space between the file. In sandy soils the closest possible fit must be obtained to prevent flow of soil material into the tile.

CHAPTER 5

Temporary Runoff Control

Temporary runoff control is important on developing sites to minimize on-site erosion and to prevent off-site sediment discharge. Temporary runoff control primarily consists of two main strategies: keeping off site water clean and managing on site sediment laden water.

Off site water that passes through an active construction site should be kept as clean as possible. This is accomplished by routing this flow through the site without opportunity to mix with untreated site runoff or by diverting clean water can be diverted around construction areas. Sediment control practices generally will be more effective, less expensive and require less maintenance by not incorporating off site water. Diversions and temporary crossings are examples of runoff controls that are designed to keep off site water clean.

Once construction begins, erosion will occur. To minimize erosion, site runoff must be managed. This starts by minimizing the amount of disturbance and maintaining existing vegetation as much as possible to reduce the volume of runoff generated and subsequent erosion. It is important that the site designer and contractor recognize these opportunities to reduce site runoff.

Sediment laden water must be routed to an appropriate sediment control device before leaving the site. Conveying runoff through stabilized temporary diversions and slope drains not only directs muddy water to treatment devices but also reduces further erosion and prevents costly re-grading associated with gully development. Effective runoff control also makes re-vegetation easier and less costly.

The practices outlined in this chapter will significantly increase the effectiveness of a sediment and erosion control plan.

5.1 Check Dams

Description

Check dams are shaped rock dams constructed in swales, grassed waterways or diversions. They reduce the velocity of concentrated flows, thereby reducing erosion within the swale or waterway. While a rock check dam may trap sediment, its trapping efficiency is extremely poor, therefore it should not be used as the primary sediment-trapping practice.

As an alternative to rock, high flow compost filter socks may be used as check dams. While the primary use of compost socks as check dams is still to reduce flow velocity and subsequent channel erosion, these will have improved sediment removal.

Condition Where Practice Applies

This practice is limited to use in small channels where it is necessary to slow the velocity of flow in order to prevent gully erosion. Applications include grassed lined conveyances that need protection from gully erosion during the vegetative establishment or temporary swales (which due to short time of service do not practically lend themselves to a non-erodible lining). See other specifications for rock lined channels, gravel riffles and practices (chapter 4) that are more appropriate for larger channels and streams.

This practice is limited to small open channels with a drainage area less than 10 acres (5 ac. for filter socks) with the objective of limiting erosion and subsequent sedimentation in downstream areas. Examples include:

1. Ditches or swales that cannot receive a non-erodible lining and still need protection to reduce erosion.
2. Use during the interim period while the grassed lining is being established.
3. Use as an aid (not a substitute) to trap sediment from construction activity.

Page updated on 3-3-14

Planning Considerations

Rock check dams and filter sock check dams are superior to straw bale dams based on their reduced maintenance and increased effectiveness and because straw bale check dams are not a specified practice in this manual.

Rock check dams and filter sock check dams shall be placed where standing water or excessive siltation will be minimized or where damage to vegetative lining will be insignificant.

Rock check dams should be considered where the ditch or swale will not be mowed until after construction is complete.

Design Criteria

See the specifications below for design guidelines. For increased sediment control of rock check dams, smaller aggregate and or filter fabric on the upstream side may be used. It should be noted that increased ponding and the subsequent increase in the height of water behind a check dam raises the potential for erosion if overtopping occurs.

Table 5.1.1 Sock materials (The Sustainable Site, 2010)

Material	5 mil HDPE	5 mil HDPE / Cotton	Multi-Filament Polypropylene (A)	Multi-Filament Polypropylene (B)
Material characteristic	Photodegradable	Biodegradable	Photodegradable	Photodegradable
Mesh Opening	3/8” (10mm)	3/8” (10mm)	3/8” (10mm)	1/8” (3mm)
Tensile Strength	26 psi (1.83 kg/cm$^{2)}$	26 psi (1.83 kg/cm$^{2)}$	44 psi (1.83 kg/cm$^{2)}$	202 psi (1.83 kg/cm$^{2)}$
% Original Strength from UV Exposure	23% at 1000 hr	ND	100% at 1000 hr	100% at 1000 hr
Functional Longevity	9 mo. -3 year	6-12 months	1-4 years	2-5 years

Maintenance

Sediment shall be removed from behind check dam once it accumulates to one-half the original height of the check dam.

Removal

Depending upon the size and type, removal of check dams may be performed by hand or mechanical means. Stone and sediment should be removed and the area graded and seeded. Sediment accumulated behind filter socks shall be removed and then these may be cut open, and the filler material dispersed or incorporated into existing soil in order to aid vegetative establishment and reduce mowing safety concerns.

Filler material shall not be spread within the flow area of the channel or where shear stresses will mobilize sediment and compost before it can be incorporated into dense vegetation. Additionally filler material shall not be spread if it will retard or reduce the existing vegetation. Mesh netting and stakes shall be removed entirely and disposed of in the proper waste or recycling facility.

Common Problems/Concerns

If the check dam materials are not entirely removed, maintenance issues or safety concerns may be created. Removal of check dams is necessary in order to allow complete vegetative establishment.

References

Tyler, R., A. Marks, B. Faucette. 2010. The Sustainable Site: Design Manual for Green Infrastructure and Low Impact Development Forester Press, Santa Barbara, CA.

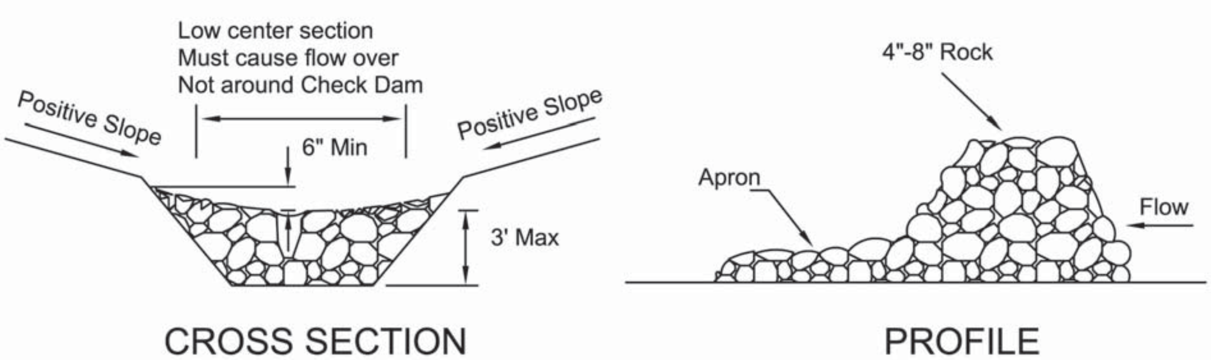
Maryland Department of Environment, 2011. Maryland Standards and Specifications for Soil Erosion and Sediment Control. Filter Log. Water Management Administration, Baltimore, MD.

Page updated on 3-3-14

Specifications
for

Rock Check Dam

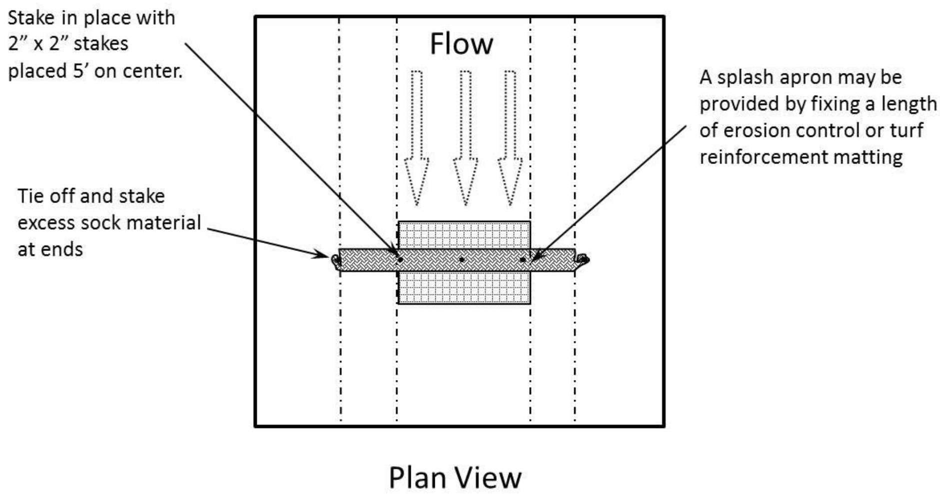
(Not to Scale)

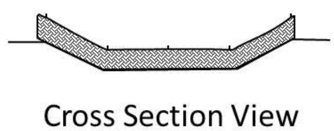


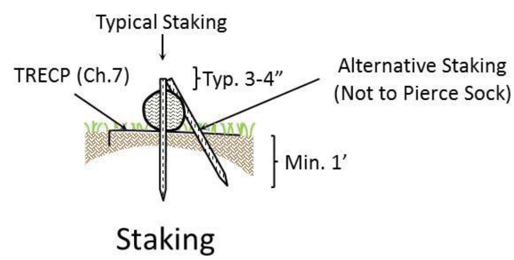
1. The check dam shall be constructed of 4-8 inch diameter stone, placed so that it completely covers the width of the channel. ODOT Type D stone is acceptable, but should be underlain with a gravel filter consisting of ODOT No. 3 or 4 or suitable filter fabric.
2. Maximum height of check dam shall not exceed 3.0 feet.
3. The midpoint of the rock check dam shall be a minimum of 6 inches lower than the sides in order to direct across the center and away from the channel sides.
4. The base of the check dam shall be entrenched approximately 6 inches.
5. Spacing of check dams shall be in a manner such that the toe of the upstream dam is at the same elevation as the top of the downstream dam.
6. A Splash Apron shall be constructed where check dams are expected to be in use for an extended period of time, a stone apron shall be constructed immediately downstream of the check dam to prevent flows from undercutting the structure. The apron should be 6 in. thick and its length two times the height of the dam.
7. Stone placement shall be performed either by hand or mechanically as long as the center of check dam is lower than the sides and extends across entire channel.
8. Side slopes shall be a minimum of 2:1.

Specifications
for

Compost Sock Check Dam







1. Compost sock netting shall use a knitted mesh fabric with 1/8-3/8 inch openings, and compost media with particle sizes 99% < 3 inches, and 60% > 3/8 inches (conforming to media described in Chapter 6 Filter Sock).
2. Compost sock check dams shall be used in areas that drain 5 acres or less.
3. Sediment shall be removed from behind the sock when it reaches ½ the height of the check dam.
4. Compost sock check dams shall be constructed with 12, 18, or 24 in diameter compost socks, and shall completely cover the width of the channel. The midpoint of the compost sock check dam shall be a minimum of 6 inches lower than the sides in order to direct flow across the center and away from the channel sides. Filter sock check dams shall be filled to a density such that they shall reach their intended height (diameter). After installation and use, they shall be considered unsuitable and in need of replacement after falling below 80% of their minimum required height (diameter).
5. Although no trenching is necessary, compost sock check dams shall be placed on a graded surface where consistent contact with the soil surface is made without bridging over gaps, rills, gullies, stones or other irregularities.
6. Place compost sock check dams so that the ends extend to the top of bank. Staking for compost sock check dams shall use 2 inch x 2 inch wooden stakes, placed 5 foot on center. Stake length shall allow them to be driven 12 inches into existing soil and allow at least 2 inches above the sock.
7. Space compost sock check dams so that the toe of the upstream dam is at the same elevation or lower elevation as the top of the downstream compost sock check dam (at the center of the channel). This will be influenced by the height of the sock and gradient of the waterway.
8. A splash apron may be needed where flows over the sock may erode the channel and undercut the compost sock check dam. Create the apron by fixing a length of Temporary Rolled Erosion Control Product (Erosion Control Matting) or Turf Reinforcement Matting starting upstream of the sock a distance equal to the sock height and extending a length two times the height of the compost sock check dam. See Chapter 7 for information regarding these materials. Materials used should be able to be left in place (e.g. biodedegradable/photodegradable TRECP) without creating problems for future mowing or maintanance of the channel.

Page updated on 3-3-14

5.2 Slope Drain

Description

A pipe or chute placed on a slope to convey surface runoff downslope without causing erosion. Slope drains provide a temporary outlet for either a diversion or terraced slope.

Condition Where Practice Applies

Slope drains are used wherever a temporary outlet is needed for a diversion, terrace or embankment. Slope drain are useful along road fills or other long fills where surface flow down the embankment would cause significant damage. This practice may be necessary where drainage cannot easily be directed to the ends of a section of fill. The maximum allowable drainage area for this practice is 5 acres.

Design Criteria

The slope drain shall be designed for non-pressure flow, and a minimum 10 year frequency event. The inlet shall be protected from scouring. In lieu of design computations, the following table may be used for sizing the drain:

Table 5.2.1 Slope Drain Sizing

Diameter (Inches)	Maximum Drainage Area (Acres)
12	0.5
18	1.5
21	2.5
24	3.5

Outlet - When the drainage area is disturbed, the slope drain shall either have inlet protection, or the drain outlet shall be directed into a sediment trapping device. A hard armored apron shall be provided below the outlet where clean water is discharged into a stabilized area or channel.

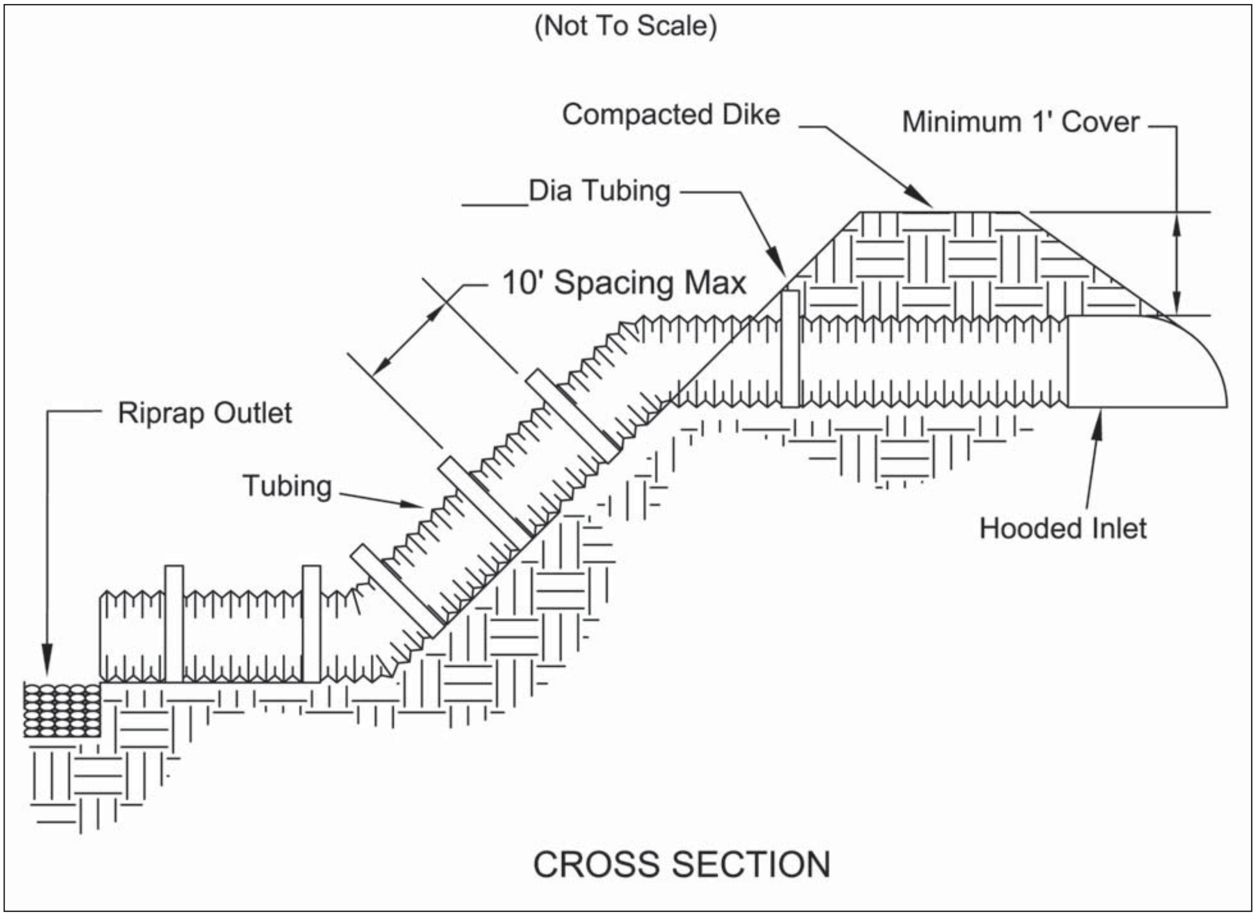
Common Problems/Concerns

Piping of soil material appears around the pipe outlet. Care should be taken to adequately compact the fill material around and beneath the pipe structure to prevent the flow of water.

Scouring of fill material occurs around the pipe entrance. A vortex may occur at the pipe entrance during high flow conditions. Armoring of the entrance or the installation of an anti-vortex device may be necessary to prevent the failure of the earth fill/dike.

Specifications
for

Slope Drain



1. The slope drain shall be constructed on a minimum slope of 3 percent.
2. All points along the top of the dike/earthfill for the storage area shall be at least one (1) foot higher than the top of the inlet pipe.
3. The pipe drain may be constructed of corrugated metal or PVC pipe. All pipe connections shall be watertight. Flexible tubing may be used, provided rigid pipe is use for the inlet, the flexible tubing is of the same diameter as the inlet, and pipe connections are made with metal strapping or watertight connecting collars. The flexible pipe shall be constructed with hold down apparatus spaced on 10 foot centers for anchoring the pipe.
4. The entrance to the pipe shall be a hooded type.
5. The soil around and/or under the pipe shall be placed in 4-inch layers and hand compacted to the top of the earth dike.
6. A riprap apron shall be installed at the pipe outlet where clean water is discharged into a stabilized area or drainageway.

5.3 Temporary Diversion

Description

A temporary diversion is a dike and/or channel constructed to:

- Direct sediment-laden runoff to a settling pond.
- Route clean runoff away from disturbed areas.
- Divert runoff to reduce the effective length of the slope.
- Direct runoff away from steep cut or fill slopes.

Conditions Where Practice Applies

This practice applies to construction areas where runoff must be redirected in order to prevent offsite sedimentation, erosion or flooding of work areas. Temporary diversions are particularly applicable to prevent flow from damaging erodible or unstable areas.

Temporary diversions are appropriate for drainage areas less then 10 acres.

Planning Considerations

It is important that diversions are properly designed, constructed, and maintained since they concentrate water flow and may increase erosion potential. Particular care must be taken in planning diversion grades. Too much slope can result in erosion in the diversion channel or at the outlet. A change of slope from a steeper grade to a flatter may cause deposition to occur, reducing carrying capacity increasing chances of overtopping and failure.

It is usually less costly to excavate a channel and form a dike or dike on the downhill side with the spoil than to build diversions by other methods. Where space is limited, it may be necessary to build the dike by hauling in diking material. Use gravel to armor the diversion dike where vehicles must cross frequently.

Build and stabilize diversions and outlets or downstream sediment facilities before initiating other land-disturbing activities.

These structures generally have a life expectancy of 18 months or less, but can be prolonged with proper maintenance.

Compare: Temporary Diversion vs. Silt Fence at the perimeter of disturbed areas

Two approaches are commonly used to intercept and treat sediment-laden runoff at the perimeter of disturbed areas: silt fence or diversions that direct runoff to settling ponds. When determining which approach is more appropriate, consider the following:

Table 5.3.1 Temporary Diversion versus Silt Fence comparison.

Temporary Diversion	Silt Fence
Flows up to 10 acres of drainage area	Sheet flow from 1/4 acre per 100 feet of fence (see silt fence specification)
Constructed on positive grade to direct runoff	Must follow the contour of the land
Durable and usually low maintenance	High maintenance
Easily constructed with earth moving equipment	Labor Intensive
Requires additional Settling facilities	Treats Runoff for Sediment
Wider Disturbed area.	Requires little space and causes less disturbance around vegetation or structures

Design Criteria

These are provided in the specifications that follow.

Operation and Maintenance

Inspect temporary diversions once a week and after every storm event. Immediately remove sediment from the flow area and repair the diversion dike as needed.

Carefully check outlets and make necessary repairs immediately.

When the area protected is permanently stabilized, remove the dike and the channel to blend with the natural ground level and stabilize all disturbed areas with vegetation or other erosion control practice.

Mow grass as needed to maintain flow in channel.

Common Problems – Suggested Solutions

Sedimentation results in channel grade decreasing or reversing, leading to overtopping – realign or deepen the channel to maintain grade.

Low point in dike where diversion crosses a natural depression results in overtopping of the dike – build up the dike.

Erosion in channel before vegetation is established results in uneven channel grade, may lead to breach of dike---repair channel and install sod or synthetic liner.

If seepage or poor drainage in channel results in poor vegetation establishment, it may be necessary to re-grade in order to create positive drainage or to install subsurface drains or stone channel bottom.

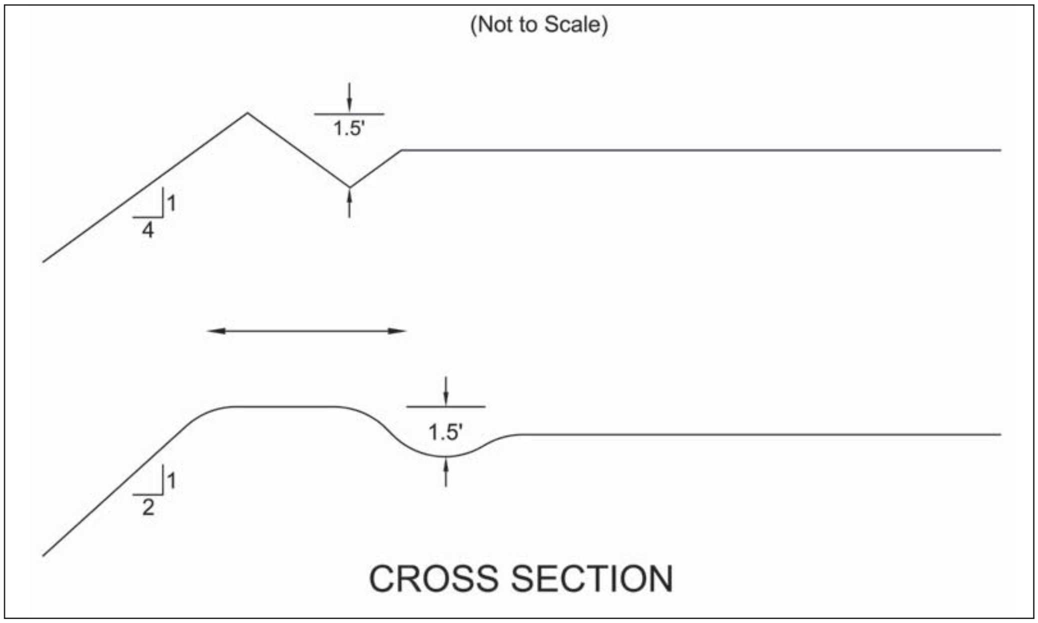
Vehicle crossings result in rutting and increased erosion – maintain the dike height, flatten the side slopes, protect the dike with gravel or hard surface at the crossing point.

Excessive velocity at the outlet results in erosion – install or repair ROCK OUTLET PROTECTION.

Excessive grade in channel results in gully erosion – repairs channel, and install an erosion resistant lining or realign to reduce the grade.

Specifications
for

Temporary Diversion



1. Drainage area should not exceed 10 acres. Larger areas require a more extensive design.
2. The channel cross section may be parabolic or trapezoidal. Disk the base of the dike before placing fill. Build the dike 10% higher than designed for settlement. The dike shall be compacted by traversing with tracked earth-moving equipment.
3. The minimum cross section of the levee or dike will be as follows: (Minimum design freeboard shall be 0.3 foot.) Where construction traffic will cross, the top width may be made wider and the side slopes flatter than specified above.

Table 5.3.2

Dike Top Width (ft.)	Height (ft.)	Side Slopes	Shape
0	1.5	4.1	Trapezoidal
4	1.5	2.1	Parabolic

4. The grade may be variable depending upon the topography, but must have a positive drainage to the outlet and be stabilized to be non-erosive.

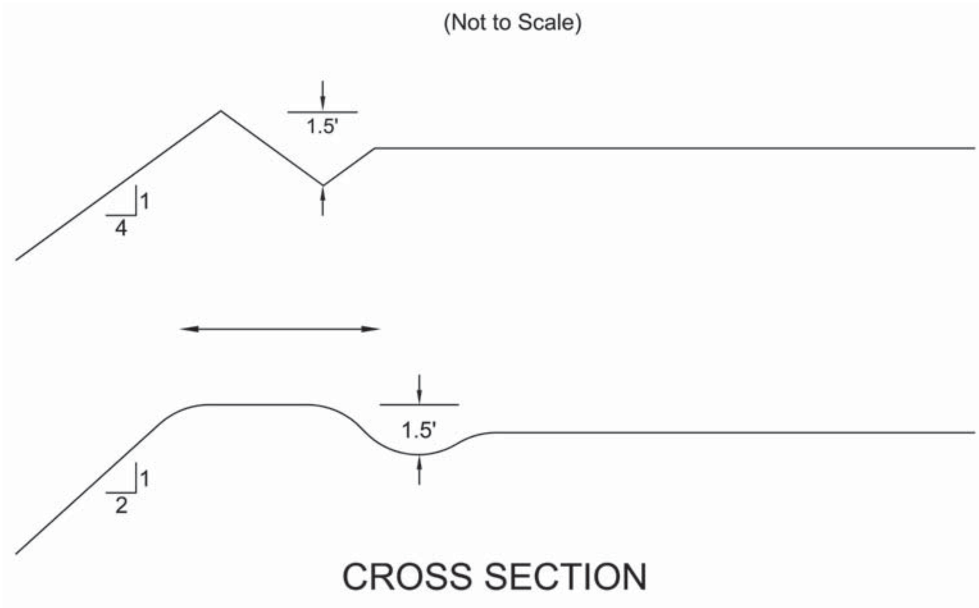
Table 5.3.3

Temporary Diversion Stabilization Treatment			
Diversion Slope	< 2 ac.	2 - 5 ac.	5 - 10 ac.
0 - 3%	Seed and Straw	Seed and Straw	Seed and Straw
3 - 5%	Seed and Straw	Seed and Straw	Matting
5 - 8%	Seed and Straw	Matting	Matting
8 - 20%	Seed and Straw	Matting	Engineered
Note: Diversions with steeper slopes or greater drainage areas are beyond the scope of this standard and must be designed for stability. Seed, straw and matting used shall meet the Specifications for Temporary Seeding, Mulching and Matting.			

5. Outlet runoff onto a stabilized area, into a properly designed waterway, grade stabilization structure, or sediment trapping facility.
6. Diversions shall be seeded and mulched in accordance with the requirements in practice standards TEMPORARY SEEDING (or PERMANENT SEEDING) and MULCHING as soon as they are constructed or other suitable stabilization in order to preserve dike height and reduce maintenance.

Specifications
for

Temporary Diversion Above Steep Slopes



1. Drainage area should not exceed 5 acres. Larger areas require a more extensive design.
2. The channel cross section may be parabolic, v-shaped, or trapezoidal. Disk the base of the dike before placing fill. Build the dike 10% higher than designed for settlement. The dike shall be compacted by traversing with tracked earth-moving equipment.
3. The minimum cross section of the levee or dike will be as follows: (Minimum design freeboard shall be 0.3 foot.)

Table 5.3.2

Dike Top Width (ft.)	Height (ft.)	Side Slopes	Shape
0	1.5	4.1	Trapezoidal
4	1.5	2.1	Parabolic

4. The grade may be variable depending upon the topography, but must have a positive drainage to the outlet and be stabilized to be non-erosive.

Table 5.3.3

Temporary Diversion Stabilization Treatment			
Diversion Slope	**< 2 ac.**	**2 - 5 ac.**	**5 - 10 ac.**
0 - 3%	Seed and Straw	Seed and Straw	Seed and Straw
3 - 5%	Seed and Straw	Seed and Straw	Matting
5 - 8%	Seed and Straw	Matting	Matting
8 - 20%	Seed and Straw	Matting	Engineered
Note: Diversions with steeper slopes or greater drainage areas are beyond the scope of this standard and must be designed for stability. Seed, straw and matting used shall meet the Specifications for Temporary Seeding, Mulching and Matting.			

5. Outlet runoff onto a stabilized area, settling pond, or into a drop structure.
6. Diversions shall be seeded and mulched in accordance with the requirements in practice standards TEMPORARY SEEDING (or PERMANENT SEEDING) and MULCHING as soon as they are constructed or other suitable stabilization in order to preserve dike height and reduce maintenance.

5.4 Stream Utility Crossing

Description

Stream Utility Crossings include pipeline, power line, or road construction projects that cross creeks or rivers. Measures used to minimize damage from the construction of utilities across streams start in the planning stages of a project and continue through site restoration. They include: determining the location of the utility, timing construction, construction techniques to reduce sediment pollution, and recreating favorable riparian conditions.

Conditions Where Practice Applies

Stream Utility Crossing apply to the following:

- Pipelines including but not limited to gas pipelines, electrical transmission lines, sanitary sewers, water lines, and etc.
- Overhead electric transmission lines,
- Road and bridge construction.

For temporary access of construction traffic across stream channels, see the specification for *Temporary Stream Crossings.*

Planning Considerations

Siting Stream Crossings – The first priority for minimizing the impacts of utility construction across streams is to minimize the length of channel disturbed. This often requires the values of the stream be acknowledged and carefully weighted through a stream assessment.

Routinely, the easiest and most inexpensive location of utilities, particularly sanitary sewers, is right down the stream channel itself. Unfortunately, this method of locating utilities causes long-term negative impacts to the stream and may necessitate higher maintenance costs to protect the utility.

Minimize the length of channel disturbed by:

- Routing utility lines well away from the stream channel and adjacent riparian area. Doing this may require more earthwork through irregular terrain and more bends in the utility.
- Crossing the stream as few times as possible.
- Crossing perpendicular to the Stream, where crossings do occur. Crossings deviating up to 30 degrees from perpendicular shall be considered perpendicular.
- Concentrate crossings of multiple utilities in one location, and/or encase into one conduit. This is most feasible where utilities are serving an individual housing development.

Within stream channels, there are areas, which are more sensitive to the work required for a utility crossing. Crossings should be located along the stream channel where they will cause the least impact. Crossings should occur where the streambanks are most stable such as the crossovers between bends where the curve of the stream changes direction or along fairly straight sections of channel. Sharp bends and steep banks, especially where showing signs of instability, should be avoided. Deep pools within the channel also should be avoided. These are locations where, during high flows, natural scour is occurring, opposed to riffle areas where deposition occurs. Generally, uniform stretches of stream will be least impacted by a utility crossing.

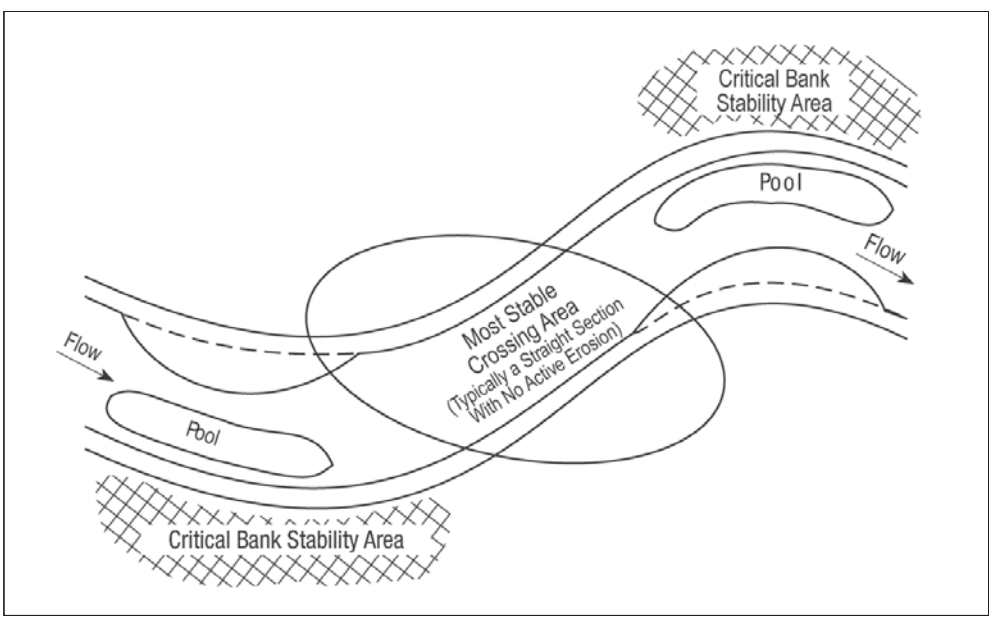


Figure 5.4.1 Stable location for utility crossing

Design Criteria

The following provide general criteria applicable to utility installations. Additional guidance is provided in the specifications that follow.

Construction Season -Utility stream crossing construction is best done during periods of low flow; generally July, August, and September. For perennial streams or important spawning streams, the worst time for construction may be during fish spawning and migration season from March 15 through June 15 or as determined for a particular stream or fish species. This should be taken into consideration along with other construction timing constraints.

Construction Method -In critical crossing situations, the method of construction may be specified. Drilling and boring utility lines under a stream channel cause much less impact than plow-in and trenching methods. Drilling and boring reduce the likelihood of erosion, as well as disturbance of the banks and bottom substrates which typically occurs with both the plow-in and trenching methods. Drilling and boring are usually more expensive and may be unreasonable for certain situations. If a utility line cannot be bored or drilled under the watercourse, the plow-in method should be used where possible. When crossing streams with the plow, a "dry run" is usually recommended prior to attaching the cable or pipe to clear out any possible stumps, logs or other obstructions.

Stream Flow Control -Stream flow should be diverted away from areas where intensive construction will occur.

Confining the Work Area -In large streams with limited areas of disturbance such as along one bank or around a bridge piling, a cofferdam or barricade can be constructed to keep the stream from continually flowing through the disturbed areas. Types of barricades include sheet pilings, sandbags, or turbidity curtains. Sheet pilings are the most durable. Sandbags can be constructed quickly in areas with shallow flow. Turbidity curtains are a geotextile material suspended from floats which hang down to the channel bottom. Unlike sheet pilings and sandbags, turbidity curtains cannot be specified for areas with strong currents or if the work area will be pumped dry.

Sediment Control: Stock piles of material shall be surrounded by silt fence or runoff routed to a sediment pond. Stabilized working pads shall be provided for the equipment in association with the construction of the crossing. Additional sediment control devices shall be implemented (ie. silt fence, sediment traps) when the trench falls within 100 feet of the stream.

Staged Construction -A cofferdam of sheet pilings or sand bags also can be used to confine, one-half of the channel until work there is completed and stabilized, then moved to the other side to complete the crossing without ever having the stream flow through the active work area.

Temporary Rerouting -When extensive or prolonged work will be done to the channel, the stream should be routed around the work area if permitted by terrain and the size of stream. Flow may be pumped around the work area or a temporary channel may be constructed. Temporary channels must be stabilized. A geotextile completely lining the channel bottom and side slopes is suitable temporary stabilization.

Limits on Each Crossing

Crossing Width -The limits of disturbance should be as narrow as possible where utilities cross streams. This includes not only construction operations within the channel itself, but also clearing done through the vegetation growing on the streambanks. The width of clearing should be minimized through the entire riparian area. To ensure minimal width of disturbance through the riparian area, materials excavated from trench construction should be placed well back from the streambanks. The width necessary for the crossing should also be clearly specified on the plans as well as the construction and clearing limits.

Duration of Construction -The time between initial disturbance of the stream and final stabilization should be kept to a minimum. The time necessary for an individual utility stream crossing varies significantly, depending on the specific project. Individual projects should be designed to encourage minimum duration of construction activity within the stream channel. Specific time limits may be specified or the crossing construction may be made dependent on other operations. For example, it could be specified that construction could not begin on the crossing until the utility line was in place to within 10 ft. of the streambanks on each side of the stream.

Fill Placed Within the Channel -The only fill permitted in the channel should be clean aggregate, stone or rock. No soil or other fine erodible material shall be placed in the channel. This restriction includes all fill for temporary crossings, diversions, and trench backfill when placed in flowing water. If the stream flow is diverted away from construction activity the material originally excavated from the trench may be used to back fill the trench.

Streambank Stabilization and Restoration - Streambanks should be restored to their original line and grade. Restoration must not result in a narrower channel or flow restriction. Stabilization of the area shall be conducted immediately upon completion of the stream crossing.

Plan specifications should define the type of stabilization, ideally woody vegetation, as described in the Stream Stabilization section of this book. Vegetation mats or Erosion Control Matting shall stabilize areas within 50' of either streambank. Some bank areas may need to be stabilized with riprap or stone in addition to matting and woody vegetation. Trees should be planted on the entire riparian area, especially the streambanks, to the extent permitted by the type of utility crossing. See the specifications for Streambank Stabilization.

Site Work Associated with Utility Stream Crossing

Runoff Control Along the Right-of-Way – Runoff and sediment controls should be used for the access road or utility easement approaching the stream crossing to prevent sediment-laden runoff from being routed directly to the stream. At a minimum distance of 50 ft. from the stream, runoff should be diverted with water bar or swales to a sediment trapping practice.

Dewatering – Trenches and excavations associated with stream crossings frequently require dewatering. Dewatering or pumping operations must not discharge turbid water directly to the stream. See the Dewatering Measures practice contained in this book for more guidance.

Permits – The specifications contained in this practice pertain primarily to the environmental impacts of stream utility crossings. The designer must also be aware that such structures are subject to the rules and regulations of the U.S. Army Corps of Engineers for instream modifications (404 permits) and Ohio Environmental Protection Agency's State Water Quality Certification (401 permits).

Maintenance

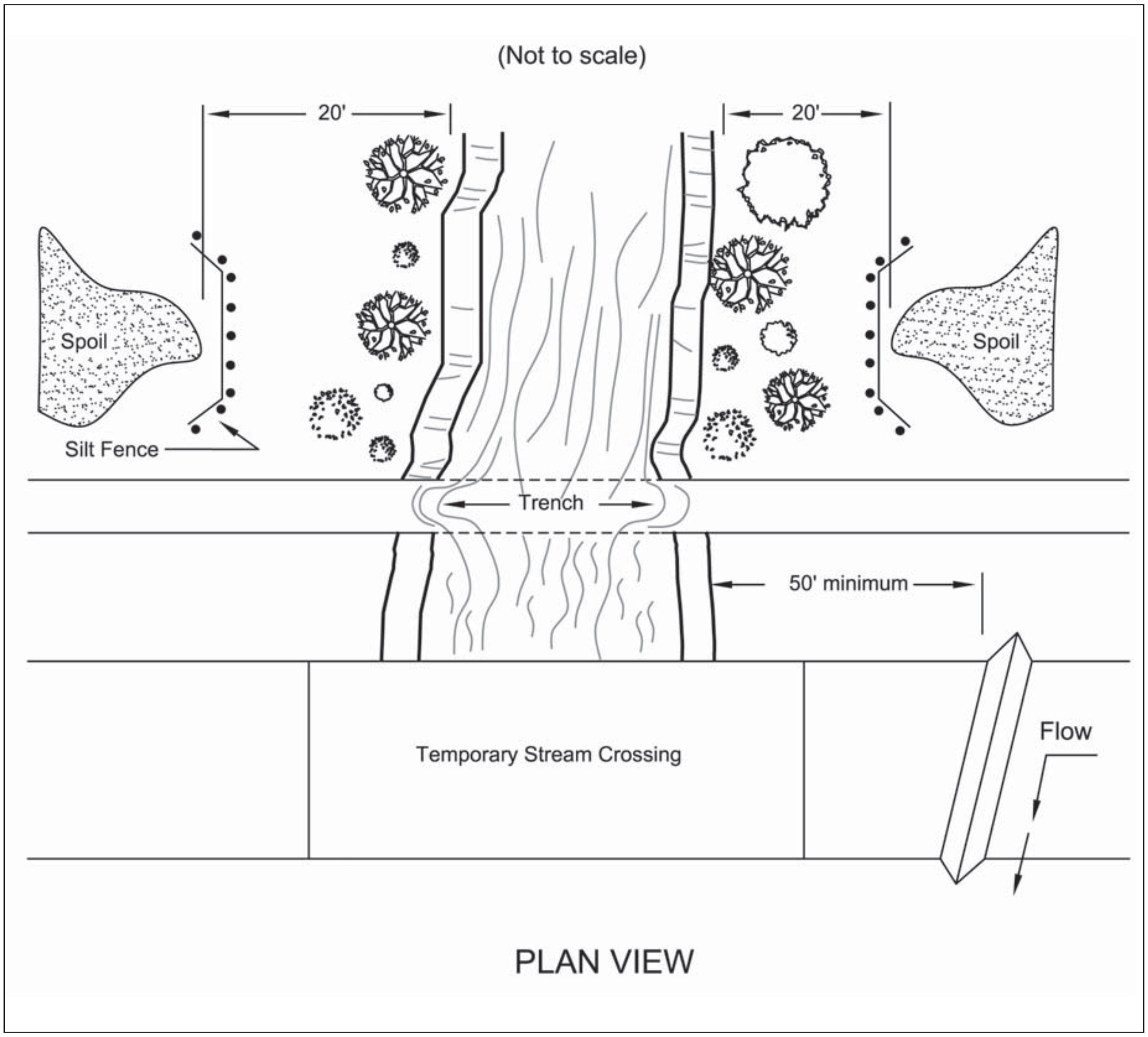
- Maintenance is essential to make sure that all items are functioning properly. This includes making sure only the areas that need to be exposed are exposed, and all other BMP practices are in good working order.
- The designated diversions should maintain the clean water through the site until the project has been completed.
- All desilting devices shall be maintained so that proper filtering occurs to the muddy water before it reenters the stream system.
- Dewatering devices shall be maintained at all times so that proper schedules can be kept for the utility crossing.

Common Problems/Concerns

- Improper staging and construction causes sediment damage because diversions, erosion control devices and dewatering does not occur in the proper order.
- Starting project during bad weather conditions so that a timely construction can occur.
- More area is opened up than for one day's construction to be completed in the stream crossing.

Specifications
for

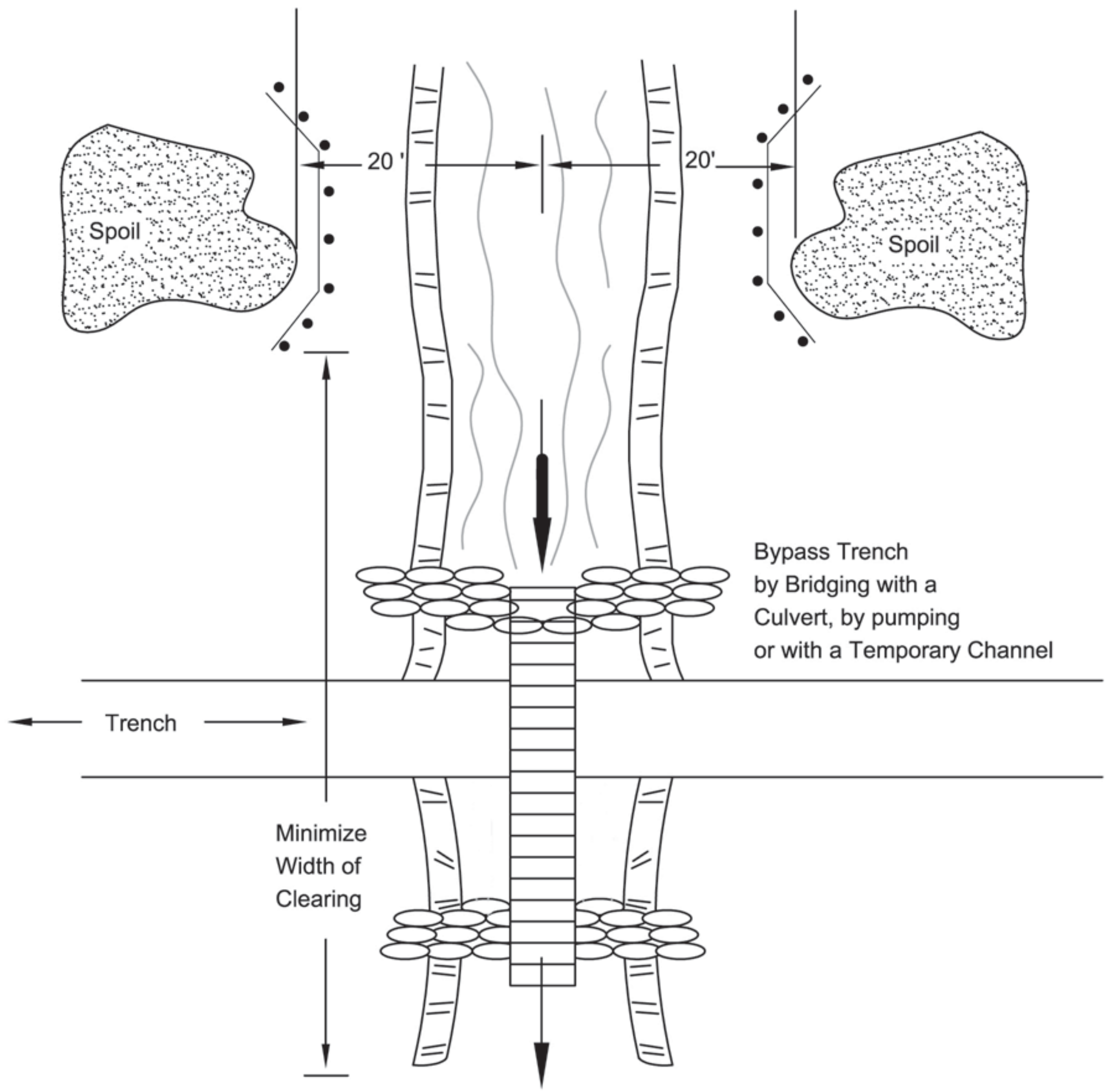
Large Stream Utility Crossing



Specifications
for

Small Stream Utility Crossing

(Not to Scale)



PLAN VIEW

Note: Show appropriate practices for temporary equipment crossings and diversion of construction runoff. See Stream Crossing

Specifications
for

Stream Utility Crossing

1. When site conditions allow, one of the following shall be used to divert stream flow or keep the flow away from construction activity.

- Drill or bore the utility lines under the stream channel.
- Construct a cofferdam or barricade of sheet pilings, sandbags or a turbidity curtain to keep flow from moving through the disturbed area. Turbidity curtains shall be a pre-assembled system and used only parallel to flow.
- Stage construction by confining first one-half of the channel until work there is completed and stabilized, then move to the other side to complete the crossing.
- Route the stream flow around the work area by bridging the trench with a rigid culvert, pumping, or constructing a temporary channel. Temporary channels shall be stabilized by rock or a geotextile completely lining the channel bottom and side slopes.

2. Crossing Width -The width of clearing shall be minimized through the riparian area. The limits of disturbance shall be as narrow as possible including not only construction operations within the channel itself but also clearing done through the vegetation growing on the streambanks.
3. Clearing shall be done by cutting NOT grubbing. The roots and stumps shall be left in place to help stabilize the banks and accelerate revegetation.
4. Material excavated from the trench shall be placed at least 20 ft. from the streambanks.
5. To the extent other constraints allow, stream shall be crossed during periods of low flow.
6. Duration of Construction -The time between initial disturbance of the stream and final stabilization shall be kept to a minimum. Construction shall not begin on the crossing until the utility line is in place to within 10 ft. of the streambank.
7. Fill Placed Within the Channel -The only fill permitted in the channel should be clean aggregate, stone or rock. No soil or other fine erodible material shall be placed in the channel. This restriction includes all fill for temporary crossings, diversions, and trench backfill when placed in flowing water. If the stream flow is diverted away from construction activity the material originally excavated from the trench may be used to backfill the trench.
8. Streambank Restorations -Streambanks shall be restored to their original line and grade and stabilized with riprap or vegetative bank stabilization.
9. Runoff Control Along the Right-of-Way -To prevent sediment-laden runoff from flowing to the stream, runoff shall be diverted with water bar or swales to a sediment trapping practice a minimum of 50 ft. from the stream.
10. Sediment laden water from pumping or dewatering or pumping shall not be discharged directly to a stream. Flow shall be routed through a settling pond, dewatering sump or a flat, well-vegetated area adequate for removing sediment before the pumped water reaches the stream.
11. Dewatering operations shall not cause significant reductions in stream temperatures. If groundwater is to be discharged in high volumes during summer months, it shall first be routed through a settling pond or overland though a flat well-vegetated area.
12. Permits -In addition to these specifications, stream crossings shall conform to the rules and regulations of the U.S. Army Corps of Engineers for in-stream modifications (404 permits) and Ohio Environmental Protection Agency's State Water Quality Certification (401 permits).

5.5 Temporary Stream Crossing

Description

A stream crossing provides construction traffic temporary access across a stream while reducing the amount of disturbance and sediment pollution. It is a temporary practice which includes restoring the crossing area after construction. Specifications for three typical kinds of stream crossings are provided: bridges, culverts and fords. Each has specific applications and each is designed to minimize stream damage by leaving banks stable and vegetated and adding only coarse stone fill to the channel.

Conditions Where Practice Applies

Where heavy equipment must be moved from one side of a stream channel to another, or where light-duty construction vehicles must cross the stream channel frequently for a short period of time. Generally, a temporary stream crossing is applicable to flowing streams with drainage areas less than 5 square miles. More exacting engineering methods should be used on larger drainage areas.

Planning Considerations

A stream and its entire riparian area should be left undisturbed to the greatest extent feasible. However where construction equipment must cross a stream channel, a temporary stream crossing is necessary. The temporary nature of stream crossings should be stressed. These structures create a channel constriction, which can cause flow backups or washouts during periods of high flow. They should be planned to be in service for the shortest practical period of time and to be removed as soon as their function is completed.

The specifications contained in this practice pertain primarily to the environmental impacts of stream crossings. From a safety and utility standpoint, the designer must also be sure that bridge spans, if used, are capable of withstanding the expected loads from heavy construction equipment. The designer must also be aware that such structures are subject to the rules and regulations of the U.S. Army Corps of Engineers for instream modifications (404 permits). For designated Scenic Rivers, approval for public projects must be obtained from the Ohio Department of Natural Resources, Division of Natural Areas and Preserves.

Locating Crossings -Stream crossings should be constructed where they will cause the least amount of disturbance to the channel and surrounding vegetation. Good locations generally include straight sections as opposed to bends and shallow areas rather than deep pools. When practical, locate and design temporary stream crossings at permanent crossing locations to minimize stream disturbance.

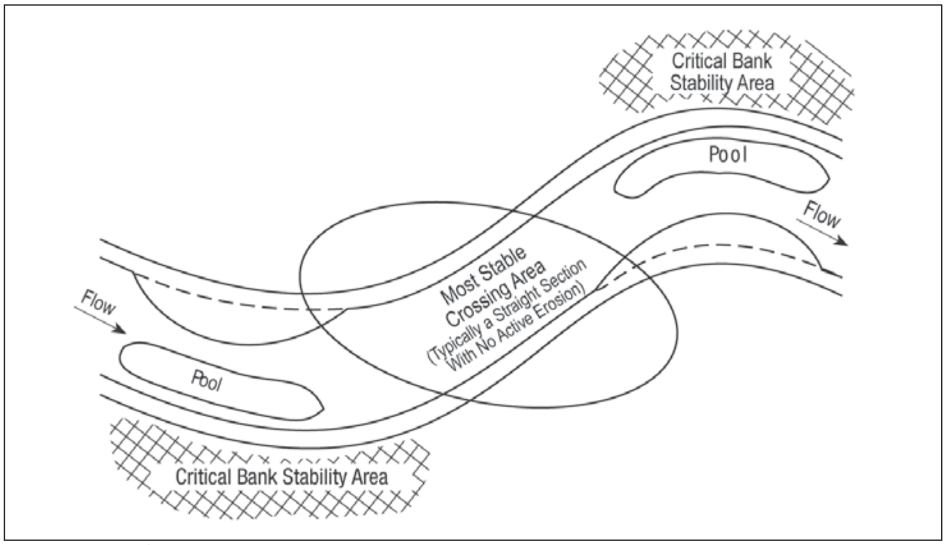


Figure 5.5.1 Stable locations for stream crossings.

Selecting Type of Stream Crossing:

Bridge:

- Can usually be installed anytime during the year.
- Bridges are preferable to the other types of stream crossings because they cause the least disturbance to the stream.
- Bridges are most applicable for narrow channels and deep channels.
- Must be adequately designed by a qualified professional for the load of the equipment expected during construction.

Culvert:

- Culvert stream crossings should NOT be constructed between March 15 and June 15 because of impacts to fish spawning.
- Culvert stream crossings are most suitable for wide-stream channels and for traffic that may be too heavy for a bridge.
- Usually constructed of readily available materials which can be salvaged after use.
- Installation and removal of culvert crossings causes considerable disturbance to the stream and greatest potential for obstruction during higher flows.

Ford:

- Stream fords should NOT be constructed between March 15 and June 15 because of impacts to fish spawning.
- Fords may be used where very little construction traffic is anticipated.
- Most applicable where normal flow is shallow or intermittent.
- Fords should not be used to cross channels with streambanks greater than 4 ft. high.
- Problems with fords include: approach sections are subject to erosion; the stone fill or surface area is subject to being washout and may need periodic replacement; mud may be directly introduced into the stream by vehicles.

Design Criteria

The following provide general criteria applicable for all types of temporary stream crossings. Additional guidance applicable to individual crossing types shall be consulted in the individual specification that follows.

Flow Capacity – For all types of crossings, the structure shall be designed to pass bankfull flow or the peak flow from a 2 year frequency 24 hour duration storm, whichever is less without overtopping. Also ensure that storms that overtop the structure can safely be conveyed without erosion, property damage or increased hazard. Flow velocity at the outlet of the structure must be non-erosive for the receiving stream.

Minimized Disturbance – Clearing shall be done by cutting and NOT grubbing except in the case of stream fords where approaches may require more grading. The roots and stumps shall be left in place to help stabilize the banks and accelerate re-vegetation.

Sediment Control – Stock piles of material shall be surrounded by silt fence or runoff routed to a sediment pond. Stabilized working pads shall be provided for the equipment in association with the construction of the crossing.

Approach Road – The road approaching the stream crossing shall not route sediment-laden runoff directly to the stream. At a minimum distance of 50 ft. from the stream, runoff shall be diverted with water bar or swales to an adequate sediment-trapping practice.

Roadway and practice materials – The aggregate for the roadway shall be a minimum of 6 inches thick stone or recycled concrete meeting one of the following ODOT coarse aggregate gradations: #1, #2, #3 or #4. The aggregate will be placed on geotextile fabric meeting the requirements in material specification filter fabric ODOT Type “B”. No soil may be used as cover or construction materials for these practices.

Width of Crossing – All crossings shall have one traffic lane. The minimum width shall be 12 feet with a maximum width of 20 feet.

Crossing Alignment – The temporary waterway crossing shall be at right angles to the stream, where approach conditions dictates, the crossing may vary 15° from a line perpendicular to the center line of the stream at the intended crossing location.

Fish Migration Barriers – Stream crossings shall not cause sudden changes in stream elevation, drops or waterfalls, which could create a barrier to migrating fish.

Trench and Groundwater Dewatering – All dewatering shall be passed through a sediment removal measure (see Dewatering Measures in this book). There should be no turbid discharges to streams resulting from dewatering.

Stabilization and Removal – Stabilization of the crossing area shall be conducted immediately upon completion of the stream crossing. The specifications should define the type of stabilization, ideally woody vegetation, as described in the Stream Stabilization section of this book. Vegetation mats or Erosion Control Matting shall stabilize the crossing of the stream, within 50' of either streambank.

To minimize obstructions and barriers, all temporary bridges, culverts, and other structures must be removed as soon as the crossing is no longer needed. However, clean stone and rock similar in size to stream bed material is usually best left in the channel because removing it causes more disturbance. Stone and rock left in the channel must be formed so that it does not impede fish passage or significantly change the slope, dimension or flow pattern of the stream.

Plans and Specifications

The plans and specifications will show the location of the crossing. They also will contain the required material specifications.

Operation and Maintenance

Inspect temporary stream crossings after runoff-producing rains to check for blockage in channel, erosion of abutments, channel scour, stone displacement, or piping along culverts. Make all repairs immediately to prevent further damage to the installation.

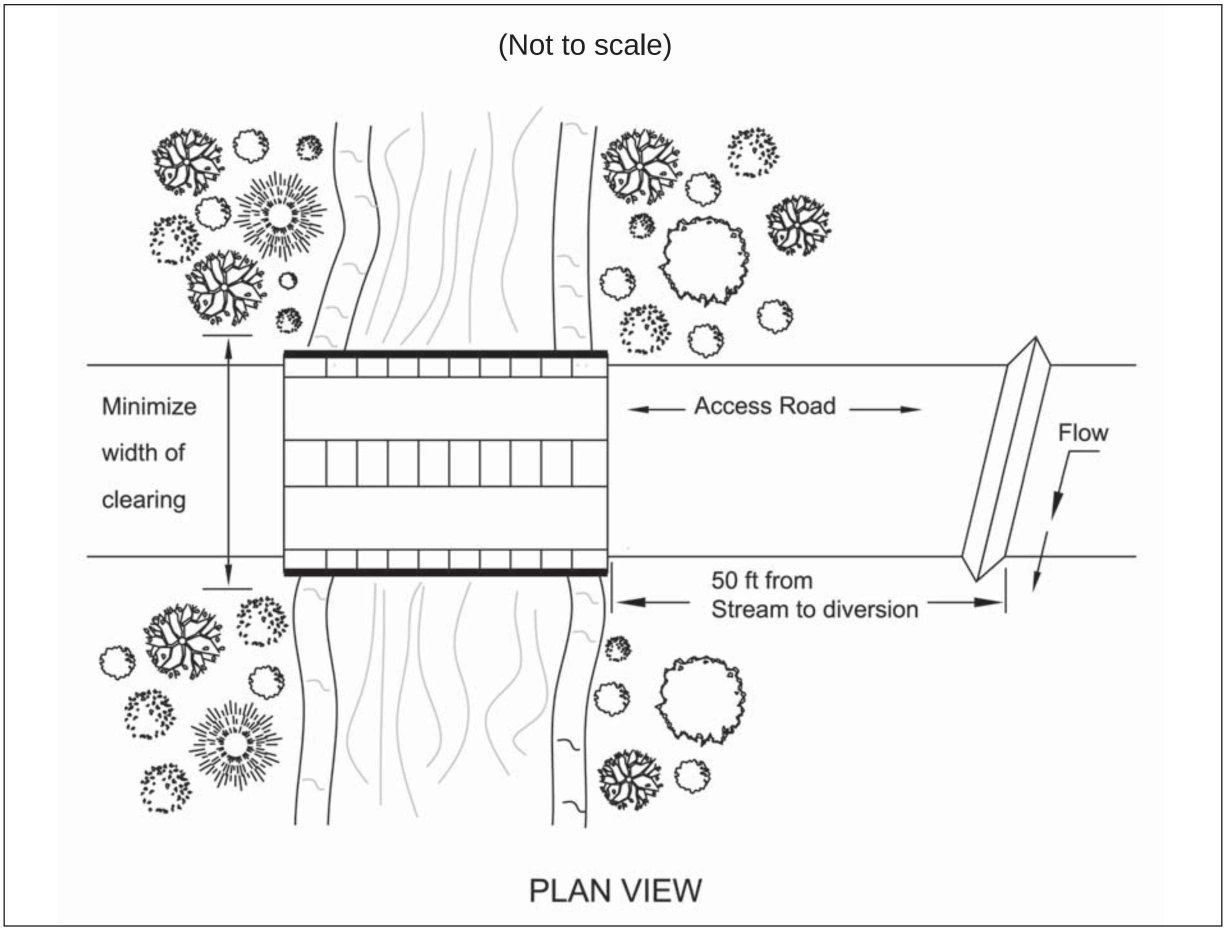
Remove temporary stream crossings immediately when they are no longer needed. Restore the stream channel to its original cross-section, and smooth and appropriately stabilize all disturbed areas.

Common Concerns

- Inadequate flow capacities and/or lack of overflow area around structure results in washout of the culvert or the bridge abatement.
- Inadequate stabilization of overflow area results in severe erosion around the bridge or culvert.
- Debris not removed after a storm event results in clogging that may cause washout of the culvert and/or bridge.
- Stone size too small causes the Ford to wash out.
- Inadequate compaction under or around culvert pipes, results in seepage and piping, causing the culvert to wash out.

Specifications
for
Temporary Access Bridge

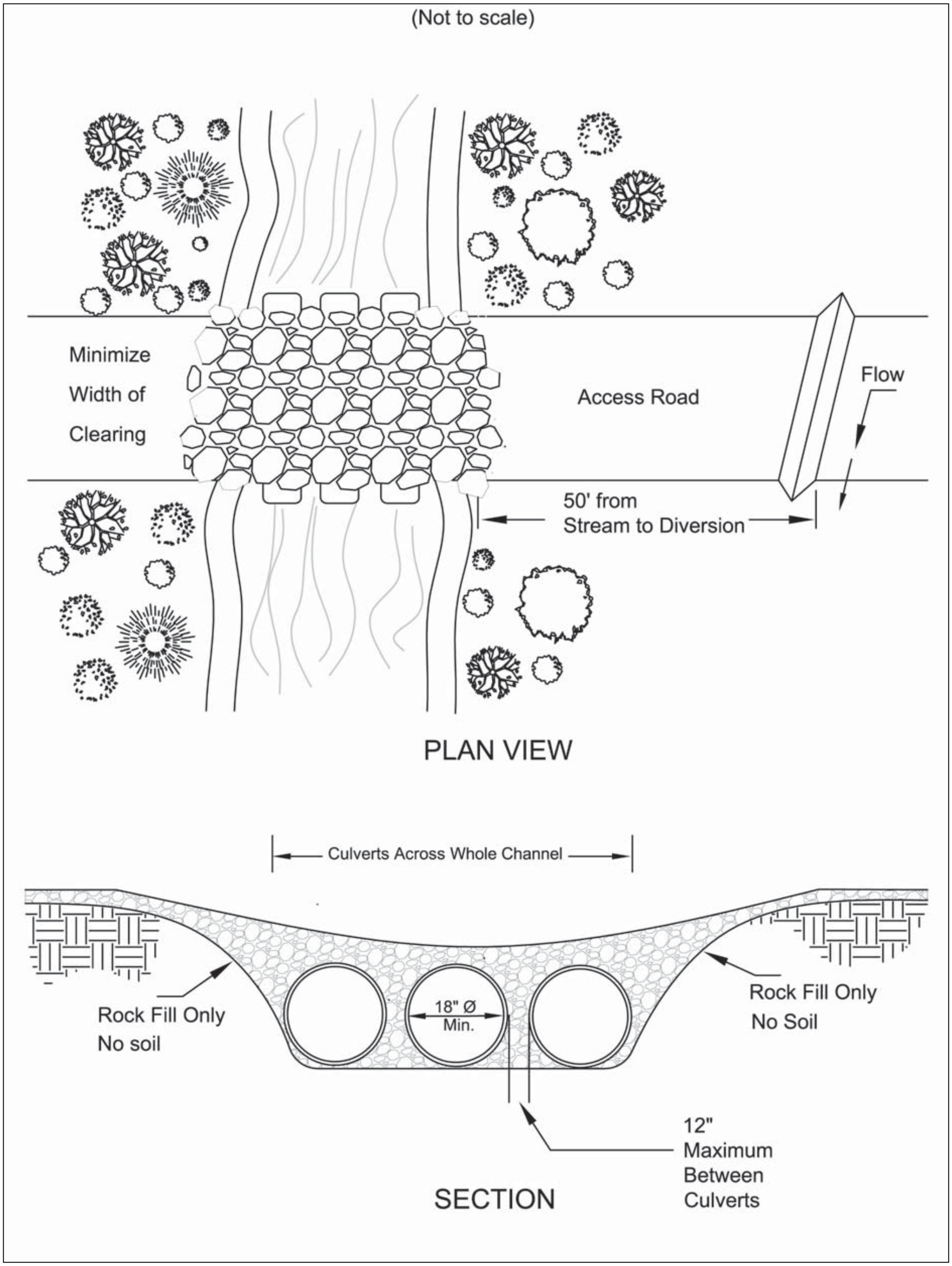
This specification does not define the strength of the temporary bridge. It shall be the designer's responsibility to select bridge construction materials with adequate strength for the anticipated construction traffic loads.



1. Stream Disturbance -Disturbance to the stream shall be kept to a minimum. Streambank vegetation shall be preserved to the maximum extent practical and the stream crossing shall be as narrow as practical.
2. Clearing shall be done by cutting NOT grubbing. The roots and stumps shall be left in place to help stabilize the banks and accelerate revegetation.
3. Water shall be prevented from flowing along the road directly to the stream. Diversions and swales shall direct runoff away from the access road to a sediment-control practice.
4. Bridges shall be constructed to span the entire channel. If the channel width exceeds 8 ft. as measured from the top-of-bank, then a footing, pier or bridge support may be constructed within the waterway. No more than one additional footing, pier or bridge support shall be permitted for each additional 8-ft. width of the channel. However, no footing, pier or bridge support will be permitted within the channel for waterways less than 8 ft. wide.
5. Some steep watersheds subject to flash flood events may require that the bridge be cabled ore secured to prevent downstream damage or hazard.
6. No fill other than clean stone free from soil shall be placed within the stream channel.

Specifications
for

Culvert Stream Crossing



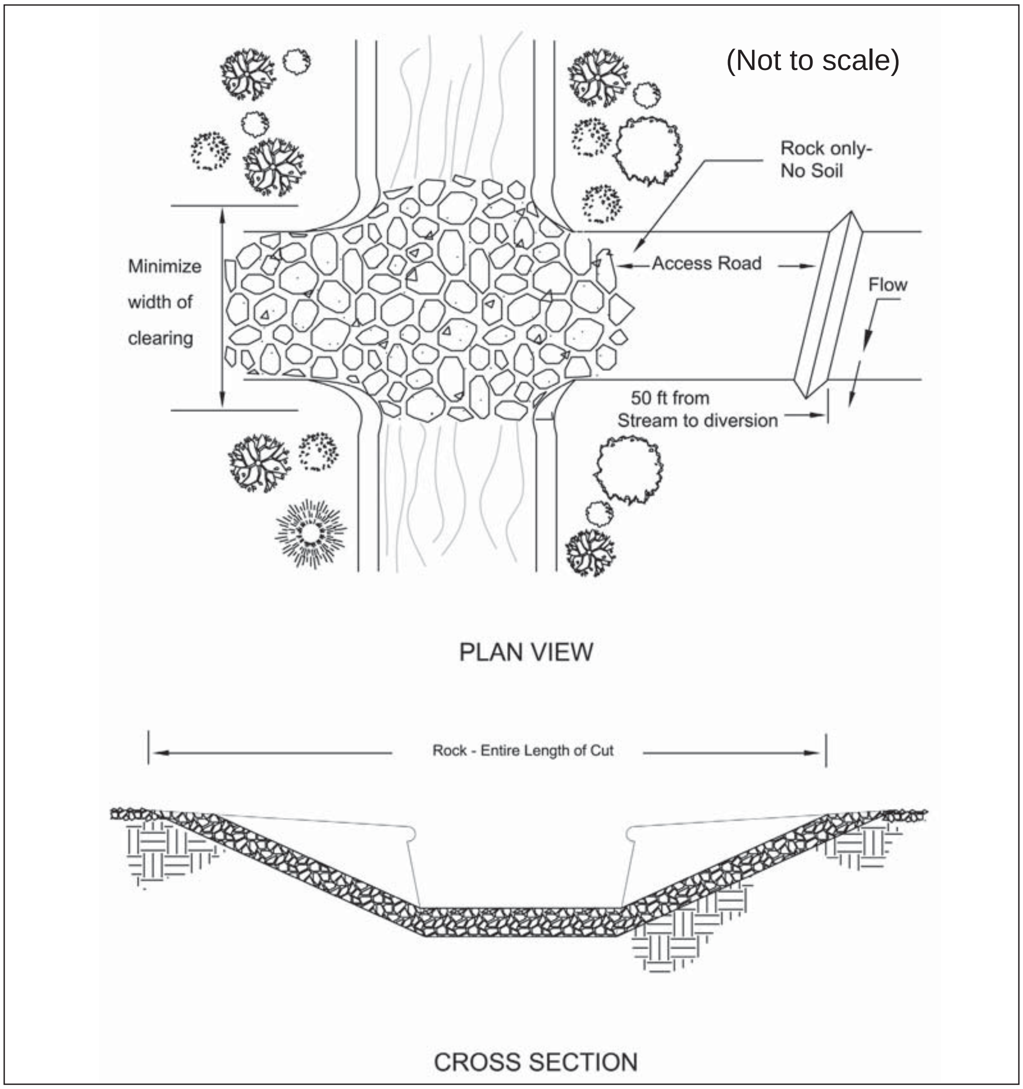
Specifications
for

Culvert Stream Crossing

1. Stream Disturbance -Disturbance to the stream shall be kept to a minimum. Streambank vegetation shall be preserved to the maximum extent practical and the stream crossing shall be as narrow as practical.
2. Clearing shall be done by cutting NOT grubbing. The roots and stumps shall be left in place to help stabilize the banks and accelerate revegetation.
3. To minimize interference with fish spawning and migration, crossing construction should be avoided where practical from March 15 through June 15.
4. Water shall not be allowed to flow along the road directly to the stream. Diversions and swales shall direct runoff away from the access road to a sediment-control practice.
5. Placement -Culverts shall be placed on the existing streambed to avoid a drop or waterfall at the downstream end of the pipe, which would be a barrier to fish migration. Crossings shall be made in shallow areas rather than deep pools where possible.
6. Culvert Size -Culvert diameter shall be at least three times the depth of normal stream flow at the point of the stream crossing. If the crossing must be placed in deep, slow-moving pools, the culvert diameter may be reduced to twice the depth of normal stream flow. The minimum size culvert that may be used is 18 in.
7. Number of Culverts -There shall be sufficient number of culverts to completely cross the stream channel from streambank to streambank with no more than a 12-in. space between each one.
8. Fill and Surface Material -All material placed in the stream channel, around the culverts and on the surface of the crossing shall be stone, rock or aggregate. ODOT No. 1 shall be the minimum acceptable size. To prevent washouts, larger stone and rock may be used and they may be placed in gabion mattresses. NO SOIL SHALL BE USED IN THE CONSTRUCTION OF A STREAM CROSSING OR PLACED IN THE STEAM CHANNEL.
9. Removal -Aggregate stone and rock used for this structure does not need to be removed. Care should be taken so that any aggregate left does not create an impoundment or impede fish passage. All pipes, culverts, gabions or structures must be removed.
10. Stabilization -Streambanks shall be stabilized. Plantings shall include woody vegetation where practical.

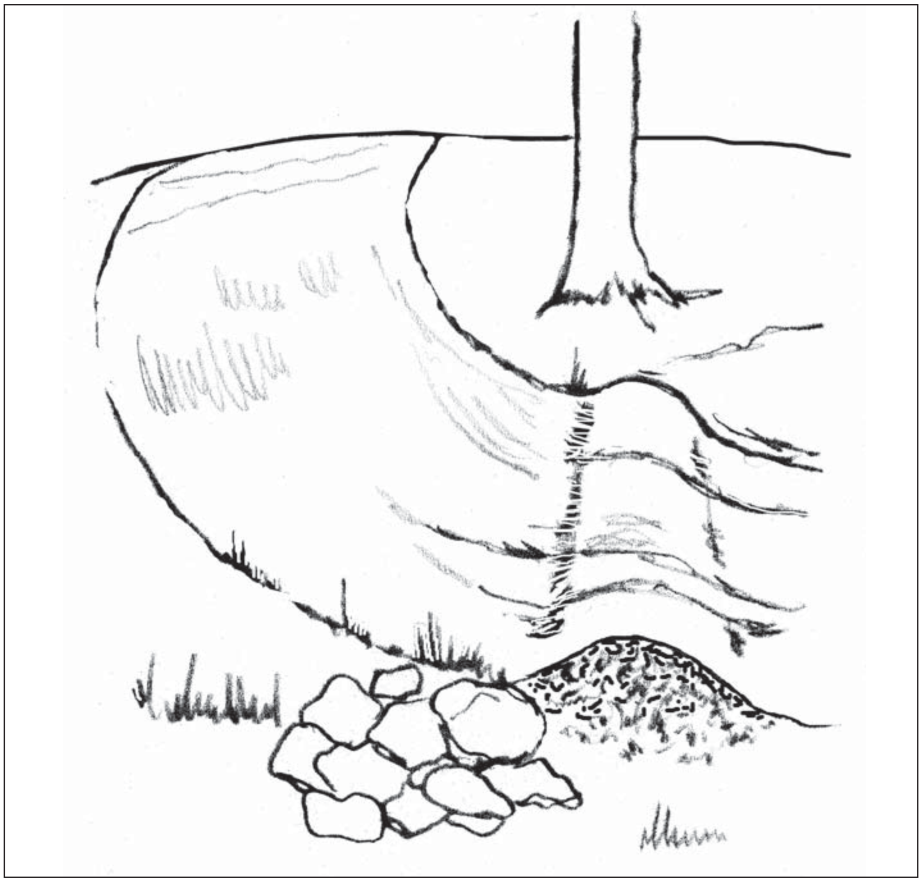
Specifications
for

Temporary Stream Ford



1. Timing -No construction or removal of a temporary stream ford will be permitted on perennial streams from March 15 through June 15 to minimize interference with fish spawning and migration.
2. Stream Disturbance -Disturbance to the stream shall be kept to a minimum. Streambank vegetation shall be preserved to the maximum extent practical and the stream crossing shall be as narrow as practical. Clearing shall be done by cutting NOT grubbing where possible.
3. Surface Runoff -Water shall not be allowed to flow along the road directly to the stream. Diversions and swales shall direct runoff away from the access road to a sediment-control practice.
4. Fill and Surface Material -All material placed in the stream channel shall be stone, rock or aggregate. ODOT No. 1 shall be the minimum acceptable size. Larger stone and rock may be used. NO SOIL SHALL BE USED IN THE CONSTRUCTION OF A STREAM FORD OR PLACED IN THE STEAM CHANNEL.
5. Removal -Aggregate, stone and rock used for the stream crossing shall NOT be removed but shall be formed so it does not create an impoundment, impede fish passage, or cause erosion of streambanks.
6. Stabilization -Streambanks shall be stabilized. Plantings shall include woody vegetation where practical.

5.6 Water Bar



Description

A water bar is a diversion constructed across the slope of an access road or utility right-of-way. Water bars are used to reduce concentrated runoff on unpaved road surfaces, thus reducing water accumulation and erosion gullies from occurring. Water bars divert runoff to road side swales, vegetated areas or settling ponds.

Conditions Where Practice Applies

Water bars are used at construction site ingress/egress points, on long sloping access roads, on temporary construction roads, or at utility right-of-ways which do not have a stable surface or where runoff would otherwise collect and cause erosion.

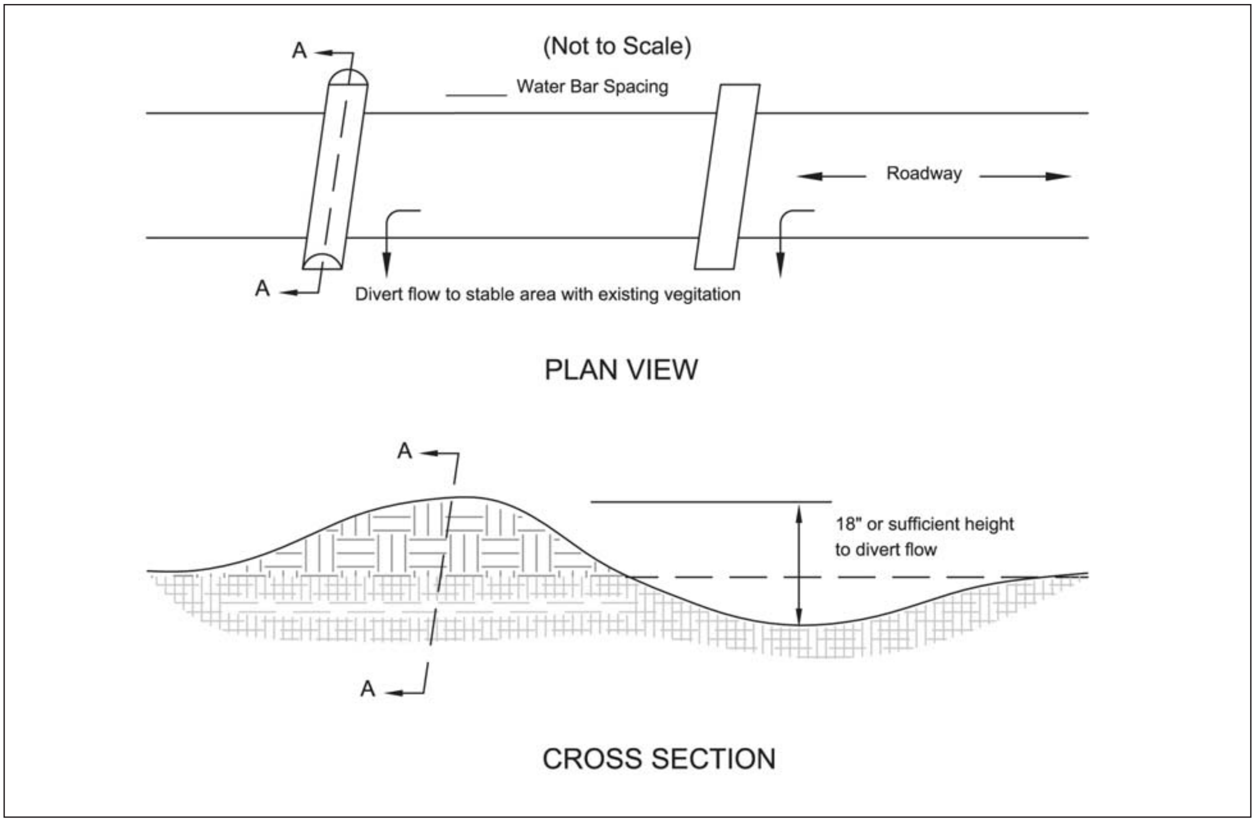
Planning Considerations

If the contributing area is disturbed, this practice should be associated with sediment traps that will receive and treat the runoff.

The outlet of each water bar must be resistant to erosion. For small contributing areas, spreading the flow into a undisturbed vegetated area may be sufficient. For larger areas or higher velocities flow may need rock outlet protection to prevent gully erosion.

Specifications
for

Water Bar



1. The minimum water bar dimensions shall be:

   Top width of berm/dike – 2 feet minimum.

   Height/depth – 18 inches unless otherwise noted on plans.

   Side Slopes – Sufficiently flat to accommodate the expected traffic.

2. The spacing between water bars shall be as noted:

   Table 5.6.1 Water Bar Spacing

Road Grade (%)	Distance (Ft.)
1	400
2	250
5	135
10	80
15	60
20	45

3. The field location shall be adjusted as needed to provide a stabilized safe outlet.

4. The diverted runoff shall be directed onto an undisturbed vegetative area, to a settling trap or basin or trap if contributing area is stable.

5. Diversions/dikes shall be compacted by traversing with equipment during construction.

6. The water bars shall be angled slightly downslope across the centerline of the travel lane.

5.7 Dewatering Measures

Description

Dewatering measures provide a stable area for receiving and treating water pumped from excavation or work areas prior to being released off the site. These practices reduce sediment impacts to downstream water resources.

Conditions Where Practice Applies

De-watering measures are used whenever water, either surface or subsurface, prevents or hinders construction activities and has the potential of contributing sediment to streams. This practice is appropriate for any kind of pumping used in conjunction with construction activities.

Planning Considerations

Construction activities often require that water be pumped from an area to facilitate work. This water often has large amounts of suspended sediments. Rather than discharge this water directly to a stream, a means to settle or remove sediment must be provided.

A dewatering plan should be prepared utilizing ground water conditions and soils information to predict areas where de-watering will likely occur. Plans should include the length of time de-watering will occur, the method of de-watering (pumping, siphon...), the discharge point(s), methods to control sediment impacts and the contents of a written log to be kept on-site. These plans may need to be approved by local authorities prior to construction.

All dewatering discharges with suspended solids should pass through a practice to remove sediments While a vegetated filter areas may be sufficient for some situations (e.g. short duration low pumping rates) many will need additional measures, such as sediment traps, filter bag or flocculation. All structures must have adequate outlet protection to prevent gully erosion. Please note that the Ohio Environmental Protection Agency will find turbid discharges to the stream resulting from any dewatering activity a violation of Ohio Revised Code 6111.04 independent of the methods employed. Therefore even if one method is selected, additional measures may be required to fully treat turbid water.

The particle size distribution, that is the relative proportion of sands, silts and clays, of a soil that is suspended will determine the difficulty of removing sediments. Soils with coarser particle size distributions (large proportion of sand) will be easier to settle out with filter strips and settling ponds. Finer particle size distributions (predominantly silt and clays) will be increasingly difficult and may need a series of measures.

Ground Water Lowering: Often dewatering wells are established to lower the ground water table for utility installation or construction. Generally, this water is free from suspended solids and may be discharged to waters of the state provided the water is not contaminated.

Measures should be taken to ensure the discharge from the de-watering wells does not flow over disturbed areas and suspend sediments, resulting in contaminated discharge. Waterways established to transport dewatering flow should be protected from erosion from the point of discharge all the way to waters of the state. Extending hoses to waters of the state will ensure the discharge remains free from suspended solids. This practice is recommended for discharges of short duration.

Water pumped from wells is about 55^{o} F, which may cause thermal impacts in some situations. High pumping rates near small streams in summer will have major changes in stream metabolism, i.e., throw off spawning. Where this potential occurs, groundwater should not be discharged directly to the stream but roughed through settling ponds or other shallow holding ponds.

The Ohio Department of Natural Resources, Division of Water requires a Water Withdraw Registration for the de-watering activities in the event the facility has the capacity of pumping in excess of 100, 000 gallons per day. This registration must be submitted to ODNR within 90 days following the completion of the project. A water withdraw registration can be obtained by contacting ODNR, Division of Water at 614-265-6735. Assistance regarding proper well installation and abandonment is also available.

Design Criteria

Vegetated Filter Areas: Densely vegetated areas may offer sufficient conditions to treat short duration discharges provided that: flow is not channelized directly to a water resource and the area encourages infiltration, slow overland flow and settling. A minimum of 100 feet is required to utilize a vegetated area. Dense grass or areas with natural depressions will provide the best conditions. Critical areas like wetlands (e.g. vernal pools) or areas with sensitive vegetation that will be damaged (smothering) by sedimentation should not be used.

Sediment trap or basin: In most cases, contaminated discharge should be directed to a sediment trap where the suspended solids can settle/filter out prior to the discharge to waters of the state. Sediment traps should have sufficient storage to receive all the discharged water from pumping and detain this water a minimum of 24 hours. The sediment storage volume is directly related to the pumping capacity and the amount of turbidity. The sediment pond should be designed to optimize the amount of travel time through the impoundment.

The sediment pond should not be more than 4 feet deep with the distance between the intake and outlet maximized to the extent practical.

Pump intakes should withdraw water from the surface of the trench or work area in order not to re-suspend or continually mix water. Continually drawing water from the floor of the area will draw the muddiest water and increase the amount of sediment that must be removed.

Geotextile Filter Bags are a increasingly common way to remove sediment from dewatering discharge. Commonly discharge is pumped into a filter bag chosen for the predominant sediment size. Filter bags are manufactured products made typically from woven monofilament polypropylene textile (coarse materials, e.g. sands) or non-woven geotextile (silts/clays). They are single use products that must be replaced when they become clogged or half full of sediment.

While they may be useful, they are generally high flow products, which have limited ability to treat fine-grained sediments. Gravity drained filter bags should apply the following:

- They should place outside of a vegetated filter area and not in close proximity to the stream or water resource.
- They must sit on a relatively flat grade so that water leaving the bag does cause additional erosion. Placing the bag on a flat bed of aggregate will maximize the flow and useful surface area of the bag.
- They should be used in conjunction with a large vegetative buffer or a secondary pond or barrier

Enhanced Treatment Through Multiple Practices. The need for further reduction in turbidity will likely require more than one treatment measure. The following are devices or measures that when used in sequence with others will reduce turbidity.

Filter bags (gravity flow) are highly variable depending on the pore size and flow rate. Typically filter bags are limited to removing large particles (small sands and large silts).

Sediment traps, weir tanks, filter boxes are effective for the removal of large particles such as sand. Their effective increases as detention times increase.

Sand Media Filters effective for removal of smaller particles such as sand and large silts. These often have the ability to backflush and thus maintain effectiveness and flow rate.

Some commercially available additives are available for further decreasing turbidity. Chitosan and chitin based additives have been shown to significantly increase the effectiveness of filtration and settling. Chitosan (Poly-D-glucosamine) is a low-toxicity product extracted from Chitin (Poly-N-acetyl-D-glucosamine), a by-product of the shellfish industry. Other products such as anionic polyacrylamide (anionic PAM) are commercially available to increase settling. Often these are utilized through wet or dry dosing mechanisms or as water runs over a gel block upstream of a settling or filtration practice. Each product should be utilized within the manufacturers specifications and tailored to the soil and site conditions.

Particulate filter units utilizing cartridges or enclosed filter bags can remove smaller particles depending on the filter size. This type of measure is usually necessary to treat clays. Filters may be need to be changed daily or more frequently.

An example of an enhanced treatment might include: dewatering a trench with a trash pump to a settling tank or pit then pumping from the settling practice to a sand media filter or to a particulate filter.

Common Problems/Concerns

Complete settling of solids within the Sediment Basin does not occur prior to discharge. The length to width ratio of the pond must be increased to lengthen travel time through the structure. In addition, flocculent may be necessary to promote settlement.

Water discharged from subsurface/ground water pumping maybe significantly lower in temperature than that of the receiving stream. The water will need pre-conditioned in order to minimize the biological affects on the stream.

References

Virginia Department of Conservation and Recreation, 2002. *Erosion & Sediment Control Technical Bulletin #2: Application of Anionic Polyacrylimide for soil stabilization and stormwater management*. http://www.dcr.state.va.us/sw/docs/anoinic.pdf

Specifications
for

De-Watering

1. A de-watering plan shall be developed prior to the commencement of any pumping activities.
2. The de-watering plan shall include all pumps and related equipment necessary for the dewatering activities and designate areas for placement of practices. Outlets for practices shall be protected from scour either by riprap protection, fabric liner, or other acceptable method of outlet protection.
3. Water that is not discharged into a settling/treatment basin but directly into waters of the state shall be monitored hourly. Discharged water shall be within +/- 5° F of the receiving waters.
4. Settling basins shall not be greater than four (4) feet in depth. The basin shall be constructed for sediment storage as outlined in Chapter 6, SEDIMENT BASIN OR SEDIMENT TRAP. The inlet and outlet for the basin shall be located at the furthest points of the storage. A floating outlet shall be used to ensure that settled solids do not re-suspend during the discharge process. The settling basin shall be cleaned out when the storage has been reduced by 50% of its original capacity.
5. All necessary National, State and Local permits shall be secured prior to discharging into waters of the state

CHAPTER 6

Sediment Controls

Sediment control is the compromise between protecting water resources and accomplishing work during grading and construction activities. Construction activities are often fully underway when Ohio's most intense storms happen, yielding significantly greater amounts of mud or sediment than other land disturbing activities such as agricultural crop production. Eventually disturbed soils will be stabilized with new vegetation, landscaping and buildings, but in the interim practices that are effective in capturing sediment are needed to prevent tons of soil from moving offsite and into wetlands, ponds, lakes, creeks and rivers.

Sediment controls are a compromise, because they don't capture all sediment. They capture the largest soil particles, (sands and large silts), but are not very effective with smaller silts and clay particles. Additionally, not all practices are equally effective. Settling ponds may be greater than 50 or 60 percent effective while the other practices (like inlet protection or silt fence) are frequently much less than 50 percent effective. Effectiveness also depends on the size of eroded particles entering the pond. For example, if suspended particles are fine silts and clays, then effectiveness of capture descreases. Conversely, if eroded particles are large silts and sands, then effectiveness will increase with the same pond design. Thus site designers must combine a strategy of phasing, construction, and rapid stabilization with the most effective sediment control practices that can be used on their site.

Sediment controls have limited effectiveness even when installed well and operating at their best. And this is often not the case. For this reason, the design, installation and maintenance of sediment control practices are critical for them to function properly.

6.1 Sediment Basin

Description

A sediment basin is a temporary settling pond that releases runoff at a controlled rate. The basin is designed to slowly release runoff, detaining it long enough to allow most of the sediment to settle. Sediment basins typically consist of a dam or embankment, the pool area for water and sediment storage, principal and emergency spillways, and a controlled dewatering device or skimmer. Secondary benefits include runoff control and preserving the capacity of downstream reservoirs, ditches, canals, diversions, waterways and streams. The entire structure may be removed when construction is complete and the drainage area is stabilized or may be converted to a detention basin for post-construction storm water management.

Condition Where Practice Applies

Sediment basins under these guidelines are limited to sites where:

- Failure of the structure would not result in loss of life, damage to homes or buildings, or interruption of use or service from private utilities.
- The drainage area is 100 ac. or less.
- The height of the dam is 25 ft. or less, as measured from the natural streambed at the downstream toe of the dam to the top of the dam.
- The basin is to be removed within 36 months after its construction.

Sediment basins exceeding any of these limits shall conform to Ohio Dam Safety Laws, local requirements, or U.S.D.A Natural Resources Conservation Service Standards and Specifications No. 378 for ponds and No. 350 for sediment basins, whichever is most restrictive.

Ohio Dam Safety Laws may apply to basins larger than 15 ac.-ft. (24,000 cy) as measured to the top of the dam. Information is available from the Ohio Department of Natural Resources, Division of Water, 2045 Morse Road, Bldg. E-2, Columbus, Ohio 43229-6605; phone (614) 265-6731.

Planning Considerations

Sediment basins and sediment traps are generally accepted methods for treating sediment-laden runoff. Sediment basins and traps are usually placed near the perimeter of construction-sites to prevent off-site sedimentation. Construction activity should be phased to allow them to remain functional for as long as possible, ideally until the area contributing runoff is stabilized with dense permanent vegetation. Settling ponds, both traps and basins, are generally recommended as the principal sediment-control practices for construction-sites. The typical components of a settling basin are shown in Figure 6.1.2 on the following page.

Effectiveness – Sediment basins do not trap all the sediment that washes into them. Sediment basins are not as effective in controlling fine particles (i.e., silt, clay) as sand and other coarse particles. Therefore, sediment basins as with all sediment controls should be used in conjunction with erosion control practices such as temporary seeding to reduce the total amount of sediment washing into them. Soil analysis may be necessary to determine whether a sediment basin will be a feasible means of preventing off-site sedimentation.

Timing – Sediment basins, along with other sediment-control practices, must be constructed as a first step in any land disturbing activity and must be functional before upslope land disturbance takes place.

Construction Phases – Sediment basins should be placed so they function through all phases of the site's development, both before and after new drainage systems are constructed.

Location – It is practical and economical to locate sediment basins where the largest storage capacity can be obtained with the least amount of earthwork, such as depressions and drainage ways (without a defined bed or bank). Do not place sediment basins in or immediately adjacent to wetlands or stream channels.

Diverting Runoff – Temporary diversions at the perimeter of construction sites are used to direct runoff to sediment basins.

Below Storm Drains – Sediment basins may be placed beyond the ends of proposed storm-drain systems. Postponing construction of the last sections of the storm drain may be necessary to provide adequate area for the sediment basin between the outlet and receiving watercourse.

Storm Drain Diversions – Storm drains may also be temporarily redirected through sediment basins during construction (Figure 6.1.1).

Utilities – Give special consideration to sediment basin location and potential interference with construction of proposed drainage ways, utilities and storm drains.

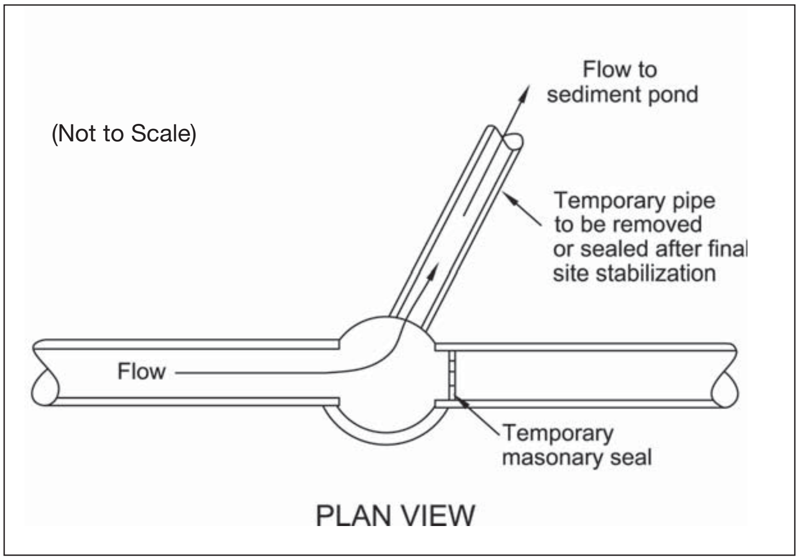


Figure 6.1.1 Temporary storm drain diversion

Design Criteria

For the purposes of this manual the design of a sediment basin is broken down into five parts which include:

1) Pool Design
2) Embankment Design
3) Dewatering Design
4) Principal Spillway Design
5) Emergency Spillway Design.

Generally accepted practices and procedures shall be followed to meet these design criteria. Sediment basins shall be designed by a registered professional engineer. Runoff computations shall be based upon the worst soil-cover conditions expected to occur in the contributing drainage area during the anticipated effective life of the structure. Runoff volumes must be computed by accepted engineering methods such as the NRCS curve number method.

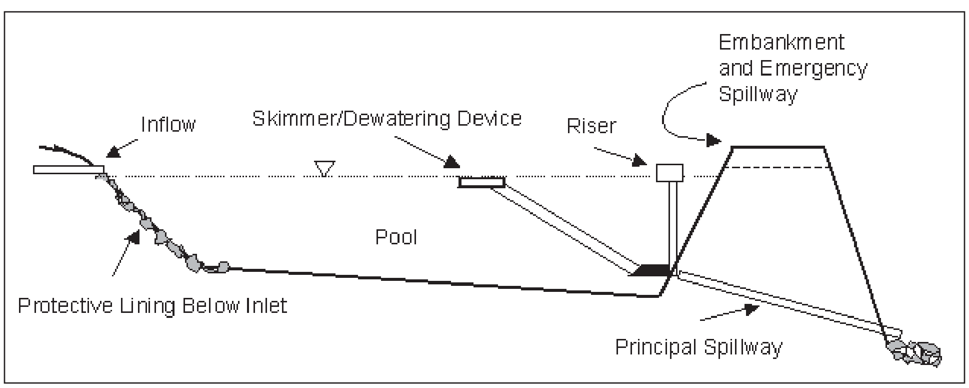


Figure 6.1.2 Typical components of a settling basin

1. POOL DESIGN:

Capacity – The minimum total design volume for the sediment basin shall consist of two components, the dewatering zone and the sediment storage zone. These zones are shown schematically in Figure 6.1.3. The volume of the dewatering zone shall be calculated for the entire drainage area by the method shown below. The drainage area includes the entire area contributing runoff to the sediment basin, offsite as well as on.

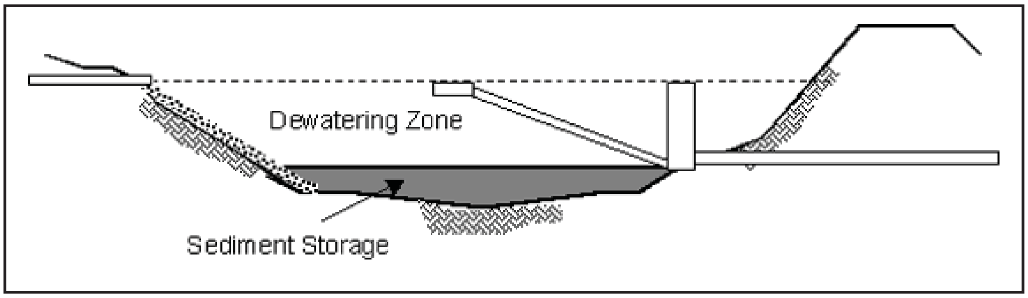


Figure 6.1.3 Pool showing dewatering area and additional sediment storage area

a) Dewatering Zone Volume -

The volume of the dewatering zone shall be a minimum of 1800 cubic feet per acre of drainage (67 yd^3/acre) or the minimum stated in the current NPDES construction general permit. Increasing this volume will increase the effectiveness of the basin, provided dewatering times are appropriately adjusted as well.

b) Sediment Storage Zone Volume -

The volume of the sediment storage zone shall be calculated by one of the following methods.

Method 1: The volume of the sediment storage zone shall be 1000 cubic feet (37 cubic yards) per disturbed acre within the watershed of the basin. OR

Method 2: The volume of the sediment storage zone shall be the volume necessary to store the sediment as calculated with RUSLE or a similar generally accepted erosion prediction model. While the sediment storage volume may extend to the expected time period of the construction project, the minimum estimated time between cleanouts shall be six months.

The total volume of the dewatering zone and the sediment storage zone shall be provided below the principal spillway elevation. The elevation at which the sediment storage zone reaches the design capacity should be designated by the top of stake located near the center of the basin. Accumulated sediment shall be removed from the basin whenever it reaches that elevation on the cleanout stake.

Depth – The pool shall be configured to maximize the optimum depth of 3 ft. Depths over 5 ft. should be avoided. The depth shall be measured to the invert of the principal spillway. These are optimum criteria and will not be feasible for all sediment basins.

Flow Length-to-Width Ratio – The length-to-width ratio shall be 4:1 or greater. If the flow length from the inlet of the basin to the principal spillway is not greater than or equal to the minimum length, either the inlet of the basin should be relocated farther away from the principal spillway, or one or more solid baffles should be used to increase the flow length within the basin. Flow length is to be measured at the elevation of the invert of the principal spillway. Where runoff from disturbed areas enters the basin from different directions, it is better to combine flows from the various areas into a single inlet into the basin rather than have multiple inlets into the basin. If multiple inlets to the basin exist, the flow length to width ratio from all inlets must be at least 4:1.

Use of Baffles in Sediment Basins – If individual situations require greater trapping efficiency or if optimum depth and length-to-width ratios are not feasible, baffles may be incorporated into the design. Baffles may be constructed of porous or solid materials depending upon their purpose. Solid baffles, as shown in Figures 6.1.4 and 6.1.5, may be used to increase the flow length within the basin.

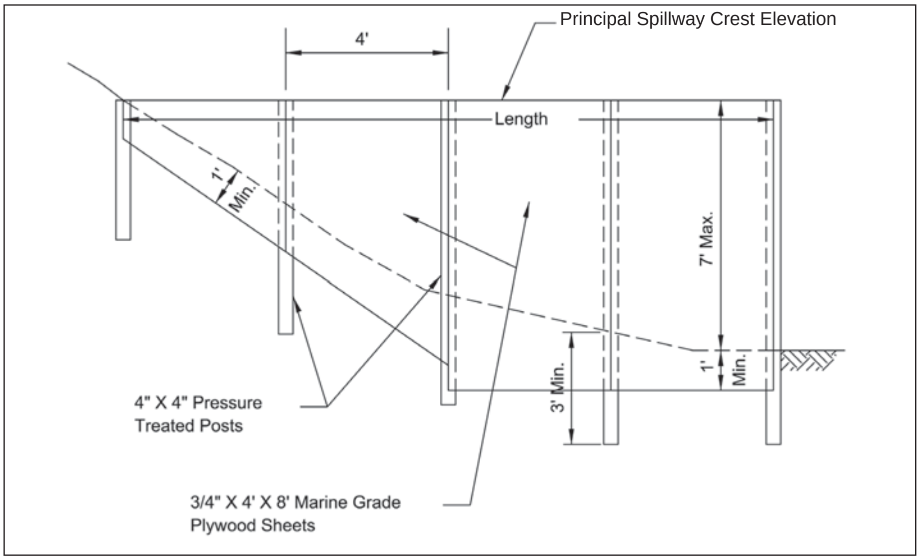


Figure 6.1.4 Typical construction of a solid baffle

Porous baffles, as shown in figure 6.1.5, are used to dampen turbulent currents and increase sedimentation. Porous baffles are typically constructed of jute matting, rock, plastic safety fence, or other material. Porous baffles typically partition the basin into two or three cells. Whether porous or solid baffles, the height shall extend to the crest elevation of the principal spillway.

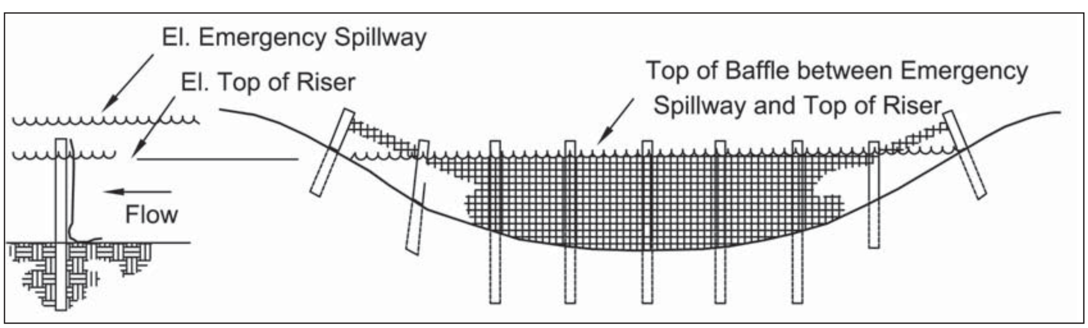


Figure 6.1.5 Porous baffle placed to increase pond efficiency (left shown in profile, right in cross-section)

Basin Inlet—A suitable protective lining for each collection channel or other device that discharges to the basin should be provided; the lining should extend to the bottom of the basin and at least 10' along the basin bottom for energy dissipation.

Safety—Sediment basins are attractive to children and can be dangerous, particularly where 2:1 or steeper side slopes lead directly into water 3 ft. or deeper. Danger is also increased where side slopes are not vegetated. Fencing and warning signs shall be installed to minimize the danger associated with sediment basins.

2. EMBANKMENT DESIGN:

Embankment Slope—Embankment slopes must be sufficiently flat to ensure stability; however, in all cases the combined upstream and downstream side slopes of the settled embankment shall not be less than 5 horizontal to 1 vertical (5:1) with neither slope being steeper than 2:1.

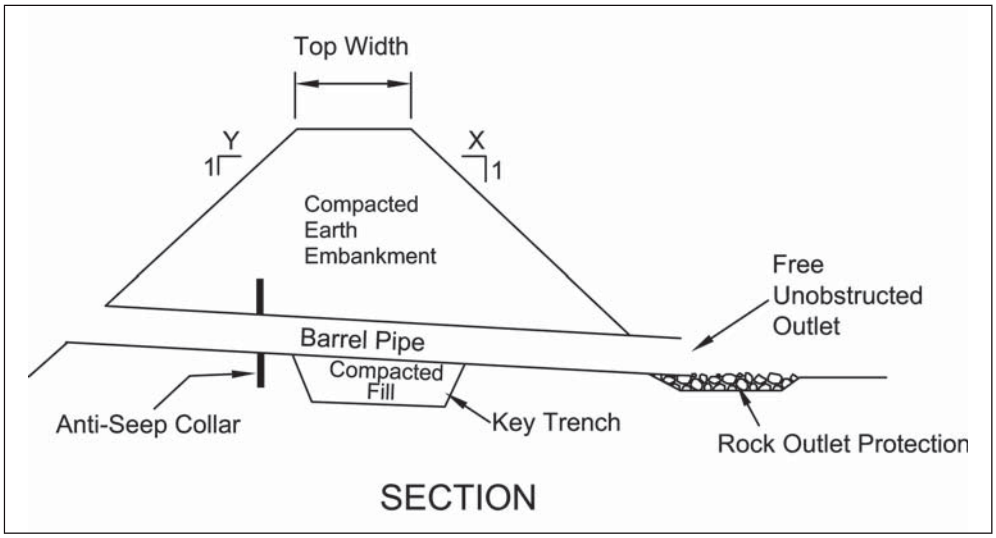


Figure 6.1.6 Embankment Design

Embankment Cutoff Trench—Use cutoff trenches to prevent seepage from flowing along the foundation of the embankment. Install cutoff trenches to a depth that extends into a relatively impervious layer. In all cases the minimum depth shall be 3 ft. and constructed of mechanically compacted material. A cutoff trench shall have a bottom width adequate to accommodate the equipment used for excavation, backfill, and compaction operations. Side slopes shall be no steeper than 1:1.

Embankment Settlement—The embankment design height shall be increased by the amount needed to ensure that after all settlement has taken place the height of the dam will equal or exceed the design height. This increase shall not be less than 5%.

Embankment Top Width—The minimum top width of the embankment shall be as shown below.

Table 6.1.1 Embankment Top Width

Embankment Height at Centerline (ft.)	Minimum Top Width (ft.)
< 15	8
15 – 20	10
> 20	12

3. DEWATERING DEVICE DESIGN:

Dewatering should be part of all sediment basins. The minimum dewatering time for sediment basins is 48 hours. The maximum dewatering time should not exceed 7 days. The lower limit of dewatering is the top of the sediment storage zone, or the top of the permanent pool if a permanent pool is used. The upper limit is the crest of the principal spillway. Sediment basins shall be dewatered using a device that discharges water from the top of the dewatering zone.

Typical methods or devices for accomplishing this may include the following: skimmers, floating pumps, siphons or other acceptable methods that provide dewatering between 48 hours and 7 days. Where ice or other reasons make dewatering from the top of the water surface impractical, multiple orifices or a single orifice may be used to dewater down to the top of the sediment storage zone. Any dewatering of the sediment zone must be accomplished using protected dewatering methods (e.g. perforated riser with gravel cone or wire mesh and filter fabric covering perforations). All of these methods are appropriate for meeting the requirements of this standard, but only sizing procedures for skimmers are included below. Concern regarding ice may justify changing outlet types during months of hardest freezing or provide frequent monitoring and mainteance as a means of preventing freezing of the skimmer.

A schematic of a skimmer is shown in figure 6.1.7 or 6.1.8. Typically a single orifice plate is placed in the discharge pipe to control water outflow or discharge. It is recommended that the orifice be placed near the water surface or floating device to allow a constant head and a more consistent discharge. Note the dewatering device is not the same as the principal or emergency spillway. However, the dewatering device outlet may be connected to the principal spillway outlet.

Sediment basins are often permanent stormwater detention facilities (wet pond, dry pond, ...) modified for sediment control use during construction. Permanent stormwater ponds and sediment basins often have different volume and drawdown requirements. Thus, if the same facility (basin) is to be used both for sediment control during construction and for permanent stormwater control, the facility will require two different outlet designs - one to be used during construction, and the other to be installed upon completion of the development. Plans should explicitly show design calculations and outlet design details for both uses and configurations.

It is recommended that calculation summaries and design details for both outlets be included on the same plan page during submittal for ease of evaluation by the reviewing agency. Table 6.1.1.a highlights summary information that should be included.

In addition, the point at which the temporary sediment basin outlet is to be replaced with the permanent stormwater basin outlet should be clearly specified on the page(s) with outlet design details.

Table 6.1.1.a Summary information for Sediment Basin versus Permanent Stormwater Facility

	Sediment Basin				Permanent Stormwater Facility			
Contributing Drainage Area (ac.)	Dewatering Volume (yd^3) or (ac-ft)	Sediment Storage Volume (yd^3) or (ac-ft)	Detention Time Min 48 hr (hours)	Sediment Control Orifice Size (in) or (in^2)	Water Quality Volume-WQv (yd^3) or (ac-ft)	Permanent Pool Volume (yd^3) or (ac-ft)	Detention Time (hours)	WQv Orifice Size (in) or (in^2)

Sizing Procedures for Skimmers

Two types of skimmer are discussed here: the Faircloth Skimmer, a patented device manufactured and sold by William Faircloth of North Carolina; and the Delaware DOT skimmer incorporated into the State of Delaware Dept. of Transportation specifications. While similarly drawing water from near the surface, the devices differ in the location of the orifice control. The Faircloth Skimmer has its orifice control located near the water surface and will maintain the same head over the orifice during dewatering. The Delaware DOT skimmer has its orifice control located at the lowest portion of the device and therefore will not have a consistent head throughout the dewatering period. Thus two different design approaches must be used in sizing the orifices for each skimmer.

Delaware DOT skimmer discharge:

Discharge from the Delaware DOT skimmer can be calculated with the orifice flow equation shown below. The discharge from the Delaware DOT skimmer will vary since the head will change as the basin is dewatered.

Orifice Flow Equation: $Q=CA(2gH)^{0.5}$

Where: Q = discharge in cubic feet per second (cfs)

C = orifice coefficient, typically a value of 0.6 is used for C

A = cross-sectional area of the orifice plate in square feet

g = acceleration due to gravity, 32.2 ft/sec2

H = head above orifice in feet, from the orifice center to the water surface

As an alternative to utilizing the orifice flow equation, the following table can be utilized to determine discharge, Q, in cfs. The average head is used with the given range (e.g. for 0-2 feet, H = 0.5 feet)

Table 6.1.2 Discharge, Q, in cfs for different orifice sizes and head above orifice (ft).

Orifice size (in.)	0' to 1'	1' to 2'	2' to 3'	3' to 4'	4' to 5'
1"	0.019	0.032	0.042	0.049	0.056
1.5"	0.041	0.072	0.093	0.110	0.125
2"	0.074	0.129	0.166	0.196	0.223
2.5"	0.116	0.201	0.259	0.307	0.348
3"	0.167	0.289	0.373	0.442	0.501
3.5"	0.227	0.394	0.508	0.602	0.682
4"	0.297	0.514	0.664	0.786	0.891

The orifice shall be designed to remove the entire volume of the dewatering zone. The minimum dewatering time for the sediment basin is 48 hours. The maximum dewatering time should not exceed 7 days. The dewatering orifice shall be designed by the following procedure or other equivalent means.

Step 1 – Knowing the size and shape of your dewatering zone, calculate the volume of water (cubic feet) in each 1-foot increment from the bottom of the dewatering zone to the top of the dewatering zone (e.g., 0'-1', 1'-2', 2'-3', 3'-4', 4'-5').

Step 2 – Select a trial orifice size, and use the chart on page 9 to determine the discharge, Q, for each 1-foot increment of head.

Step 3 – Divide each volume calculated in step 1 by the corresponding Q (step 2) to get the total dewatering time.

Step 4 – Sum the dewatering times for the 1-foot increments to get the total dewatering time. Make sure to convert the units from seconds to days (86,400 seconds/day).

Step 5 – If the dewatering time is less than 2 days or greater than 7 days, select a different orifice size and repeat steps 2-5.

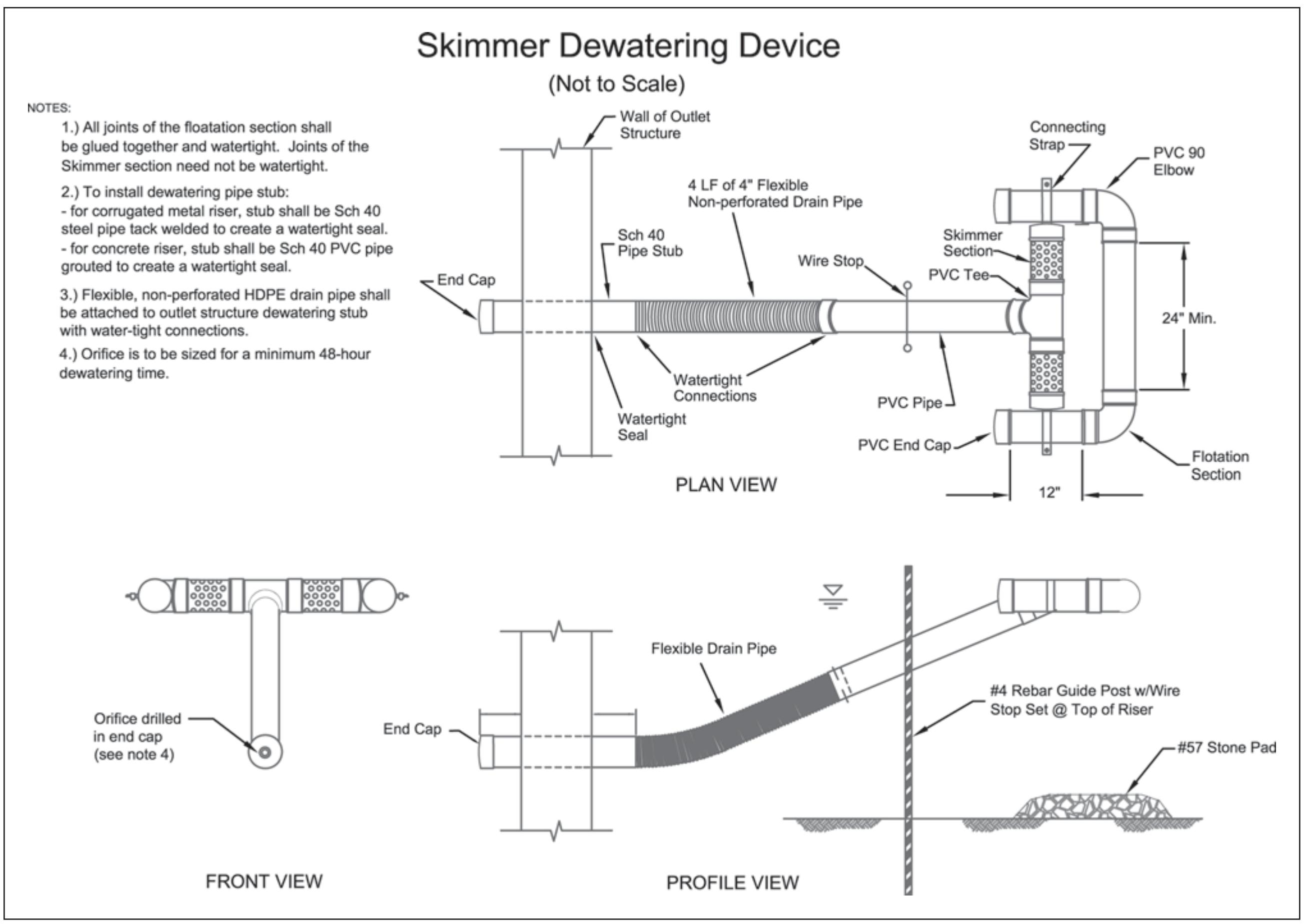


Figure 6.1.7 Delaware Dept. of Transportation Skimmer

Faircloth skimmer discharge:

The typical components of the Faircloth skimmer are shown in Figure 6.1.8. This skimmer consists of three primary parts: the arm assembly, the water entry unit and the “C” enclosure keep debris from water entrance. The “C” enclosure floats on the water surface and suspends the water entry unit just below the water surface. The arm assembly transports the water from the water entry unit to the basin’s principal spillway barrel. Water discharge rate is to be controlled by an orifice located at the connection between the water entry unit and the arm assembly.

Instructions for design, installation and maintenance of Faircloth skimmers is available from the J.W. Faircloth & Sons Company at www.fairclothskimmer.com.

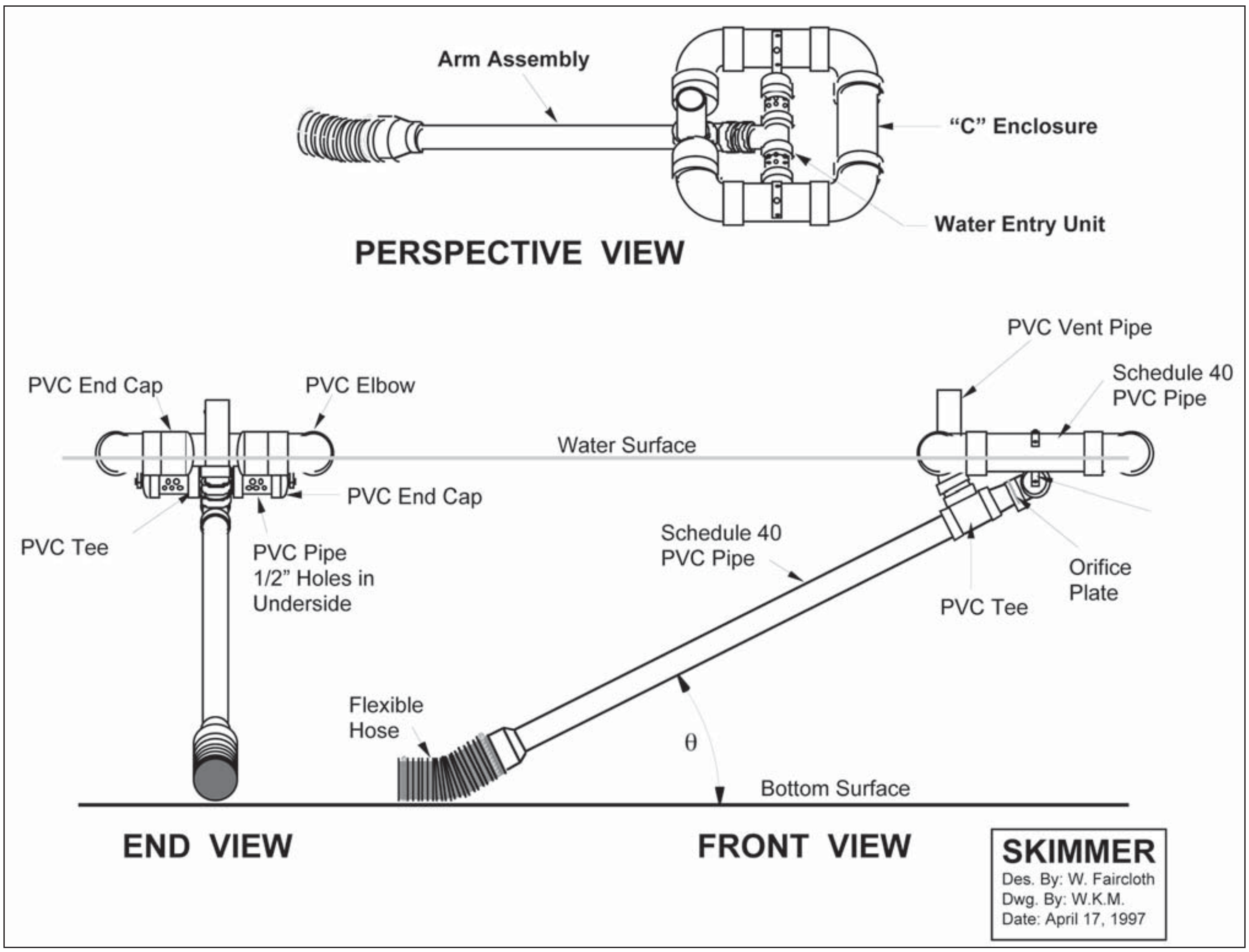


Figure 6.1.8 Faircloth Skimmer Schematic Developed by Warren Faircloth, North Carolina (Penn State Ag and Biol. Eng Fact Sheet F-252)

4) PRINCIPAL SPILLWAY DESIGN:

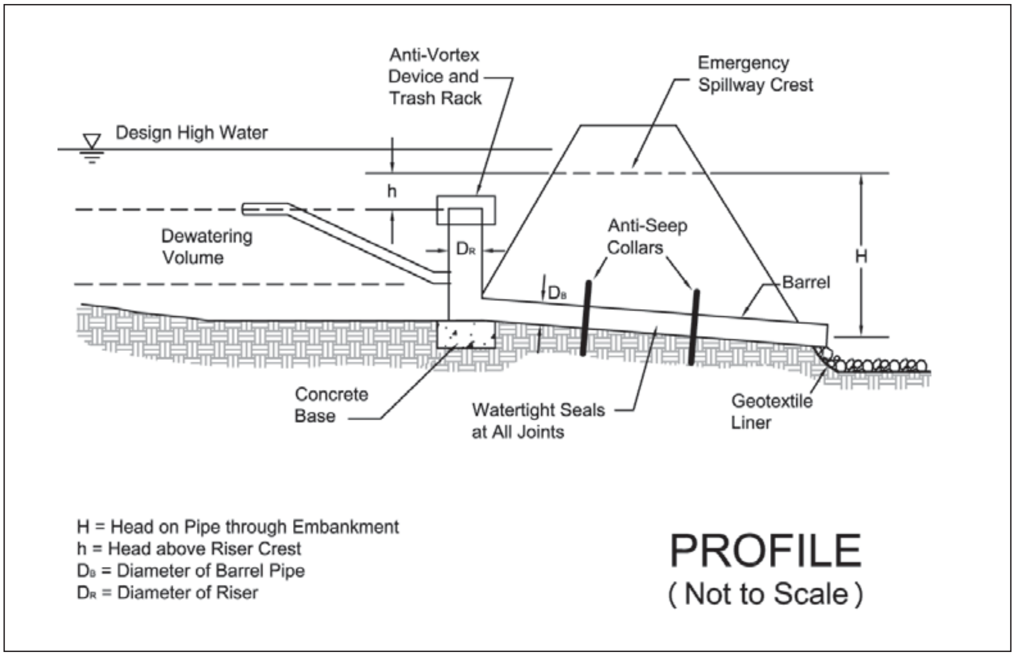


Figure 6.1.10 Principal Spillway Design

Capacity – The principal spillway must be designed to pass the discharge from a 10-year, 24-hour duration storm when the water surface is at the crest of the emergency spillway.

Materials – Principal spillway materials shall meet the NRCS standard and specification for ponds (NRCS Field Office Technical Guide standard 378).

Configuration – Configurations consisting of a riser and barrel (non-perforated) principal spillway with a skimmer dewatering device are encouraged although other configurations may be utilized provided the dewatering time is between 48 hours and 7days.

Staging Requirements – The principal spillway crest elevation must be a minimum of 1 ft. below the elevation of the emergency spillway crest. The minimum difference in elevation between the crest of the emergency spillway and settled top of dam shall be 2 ft., or 1 ft. above the water surface in the reservoir with the emergency spillway flowing at design depth, whichever is greater.

Sizing Procedures for Riser and Barrel – A principal spillway riser and barrel design procedure is shown below. The minimum riser diameter is 15", and the minimum barrel diameter is 12".

1. Determine Q from the design criteria. The principal spillway must be designed to pass the discharge from a 10-year, 24-hour duration storm when the water surface is at the crest of the emergency spillway.

2. Determine h as the difference in elevation between the crests of the principal spillway and the emergency spillway as shown in Figure 6.1.10.

3. Determine H as the difference in elevation between the barrel outlet and crest of the emergency spillway as shown in Figure 6.1.10.

4. Using Q and h, refer to the Riser Inflow Curves (Figure 6.1.11 for CMP), and find the riser size required. Different materials will require using alternative Riser Inflow (Inlet) Curves or equations.

5. Using Q and H, refer to the Barrel Size table (Table 6.1.3) to find the appropriate barrel size.

6. Compare barrel flow (Q_{pipe}), weir flow at the riser (Q_{weir}), orifice flow at the riser ($Q_{orifice\text{-}high}$), and flow at the entrance to the barrel ($Q_{orifice\text{-}low}$) in order to insure the lowest or controlling flow of the principal spillway meets the 10-year, 24-hour flow. Equations are shown below except those provided with figures.

$Q_{weir} = CLH^{1.5}$

where Q = Discharge across weir (cfs)
C = Weir coefficient
L = Length of weir (circumference of riser, ft)
H = Head above the orifice (ft)

$Q_{orifice\text{-}high} = CA(2gh)^{0.5}$

where Qorifice-high = Discharge due to orifice flow at the riser
C = Coefficient of discharge
A = Cross-sectional area of the riser (ft^2)
g = Acceleration due to gravity, (32.2 ft/sec^2)
h = Head above the riser, from the riser crest to the water surface (ft)

$Q_{orifice\text{-}low} = CA(2gh)^{0.5}$

where Qorifice-low = Pipe discharge at the barrel entrance
C = Coefficient of discharge
A = Cross-sectional area of the barrel conduit (ft^2)
g = Acceleration due to gravity (32.2 ft/sec^2)
h = Head above barrel entrance from orifice to water surface (ft)

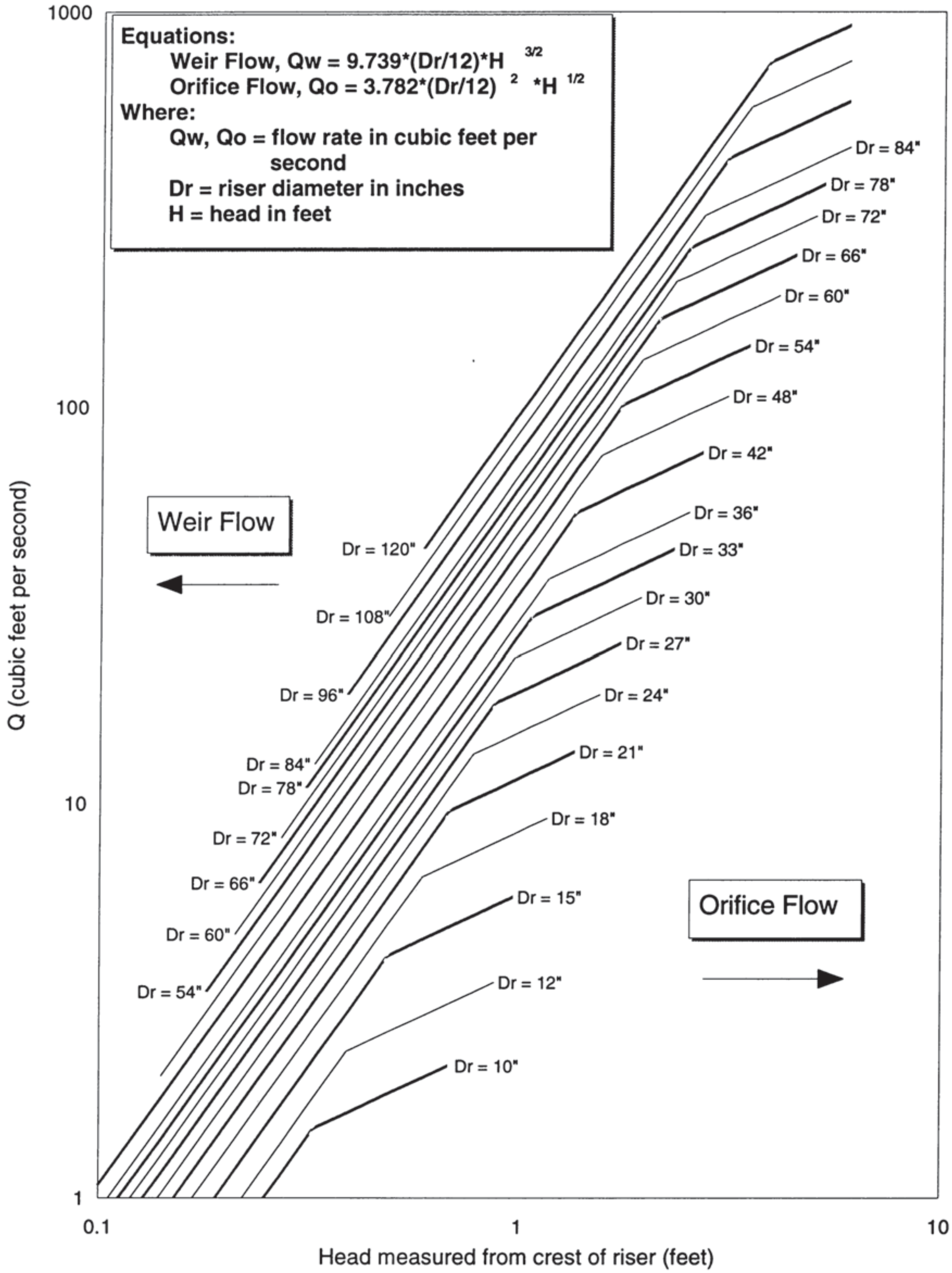


Figure 6.1.11 Riser Inflow Curves

Table 6.1.3 Barrel Size--For Corrugated Metal Pipe Principal Spillway
Based on flow rate (Q) and head (H)

Head, H (ft.)	Barrel Diameter (in.)										
	12	**15**	**18**	**21**	**24**	**30**	**36**	**42**	**48**	**54**	**60**
	Flow Rate, Q (cfs)										
1	1.98	3.48	5.47	7.99	11.0	18.8	28.8	41.1	55.7	72.6	91.8
2	2.80	4.92	7.74	11.3	15.6	26.6	40.8	58.2	78.8	103	130
3	3.43	6.02	9.48	13.8	19.1	32.6	49.9	71.2	96.5	126	159
4	3.97	6.96	10.9	16.0	22.1	37.6	57.7	82.3	111	145	184
5	4.43	7.78	12.2	17.9	24.7	42.1	64.5	92.0	125	162	205
6	4.86	8.52	13.4	19.6	27.0	46.1	70.6	101	136	178	225
7	5.25	9.20	14.5	21.1	29.2	49.8	76.3	109	147	192	243
8	5.61	9.84	15.5	22.6	31.2	53.2	81.5	116	158	205	260
9	5.95	10.4	16.4	24.0	33.1	56.4	86.5	123	167	218	275
10	6.27	11.0	17.3	25.3	34.9	59.5	91.2	130	176	230	290
11	6.58	11.5	18.2	26.5	36.6	62.4	95.6	136	185	241	304
12	6.87	12.1	19.0	27.7	38.2	65.2	99.9	142	193	252	318
13	7.15	12.6	19.7	28.8	39.8	67.8	104	148	201	262	331
14	7.42	13.0	20.5	29.9	41.3	70.4	108	154	208	272	343
15	7.68	13.5	21.2	30.9	42.8	72.8	112	159	216	281	355
16	7.93	13.9	21.9	32.0	44.2	75.2	115	165	223	290	367
17	8.18	14.3	22.6	32.9	45.5	77.5	119	170	230	299	378
18	8.41	14.8	23.2	33.9	46.8	79.8	120	174	236	308	389
Length L (ft.)	**Correction Factors for Pipe Lengths**										
20	1.53	1.47	1.42	1.37	1.34	1.28	1.24	1.20	1.18	1.16	1.14
30	1.36	1.32	1.29	1.27	1.24	1.21	1.18	1.15	1.13	1.12	1.11
40	1.23	1.21	1.20	1.18	1.17	1.14	1.12	1.11	1.10	1.09	1.08
50	1.14	1.13	1.12	1.11	1.10	1.09	1.08	1.07	1.06	1.06	1.05
60	1.06	1.06	1.05	1.05	1.05	1.04	1.04	1.03	1.03	1.03	1.02
70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80	.95	.95	.95	.96	.96	.96	.97	.97	.97	.98	.98
90	.90	.91	.91	.92	.92	.93	.94	.94	.95	.95	.96
100	.86	.87	.88	.89	.89	.90	.91	.92	.93	.93	.94

Barrel Size Chart

Riser Base – The principal spillway must be weighted to prevent flotation. The minimum factor of safety against flotation shall be 1.1. If concrete is used for the weighted riser base, the formula shown below may be used in calculating the required volume of concrete.

$$V = 0.62\, HD_R^2 - \frac{HW_R}{87.6}$$

Where:
- H = Height of Riser (ft.)
- D_R = Diameter of Riser (ft.)
- W_R = Weight of Riser (lb./ft.)
- V = Volume of Concrete (ft.^{3})

Trash Rack and Anti-Vortex Device—To prevent pipes from becoming clogged with straw or construction debris, a trash rack should be used. However, if conditions make clogging unlikely, a trash rack may not be necessary.

Seepage Control Along Principal Spillway—Seepage along the principal spillway conduit extending through the embankment shall be controlled by use of a filter and drainage diaphragms, or anti-seep collars. The placement and design of these controls shall meet requirements as set forth in the NRCS standard and specification for Ponds (378).

Outlet Protection—The discharge from a sediment basin shall be designed, to prevent accelerated erosion or sedimentation. Typical alternatives include riprap or concrete structures, storm sewers, and similar means that dissipate the energy without causing erosion to the downstream channel or stilling basin.

5) EMERGENCY SPILLWAY DESIGN:

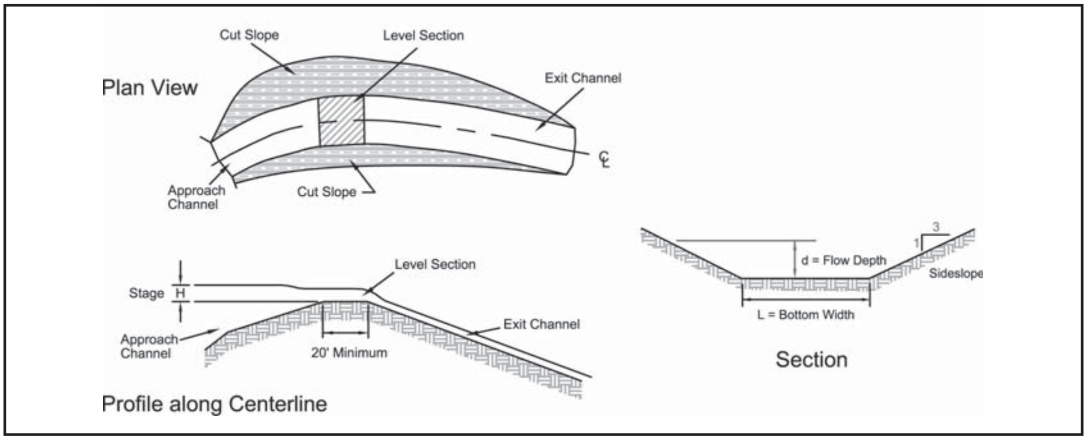


Figure 6.1.12 Emergency Spillway Design

Location and Shape—Constructed earth spillways shall be trapezoidal and located in undisturbed ground. It must not be constructed over the embankment. Spillways should have an approach channel, a flat control section, and an exit channel. Side slopes of the trapezoidal spillway are typically 3:1 or flatter. The exit channel shall be lined with grasses or riprap as appropriate, based on channel velocities.

Capacity—The capacity of the emergency spillway shall be that required to pass the peak flow from a 25-year, 24-hour storm less any reduction creditable to pipe conduit discharge detention storage and routing.

Emergency Spillway Sizing Procedure—Three methods for sizing the emergency spillway are shown below.

1) Utilize tables provided in Chapter 11 of the NRCS' Engineering Field Handbook for determining emergency spillway capacity.
2) Utilize the weir equation with the level being equal to 20 or 25 feet:

$$Q=CLH^{1.5}$$

Where this procedure is used, the maximum value of "C" should be 2.8. "L" is the bottom width of the spillway at the crest, and "H" is the height of water in the pond-above the spillway crest.

3) Having determined the design discharge "Q", find the spillway width and stage required in the Capacity of Earth Spillways table below. The stage is the difference between the pond surface and the crest of the emergency spillway.

Staging Requirements—The principal spillway invert elevation must be a minimum of 1 ft. below the elevation of the emergency spillway crest. The minimum difference in elevation between the crest of the emergency spillway and settled top of dam shall be 2 ft., or 1 ft. above the water surface in the reservoir with the emergency spillway flowing at design depth, whichever is greater.

Exit Channel Outlet Protection—The discharge from an emergency spillway shall be designed to prevent accelerated erosion or sedimentation. Typical alternatives include vegetation, riprap, concrete structures, and similar means that dissipate energy without causing erosion.

Table 6.1.4 Capacity of Earth Spillways

Stage (ft.)	Bottom Width (ft.)																
	8	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**
	Flow Rate Q (cfs)																
0.5	6	7	8	10	11	13	14	15	17	18	20	21	22	24	25	27	28
0.6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	35	37	39
0.7	11	13	16	18	20	23	25	28	30	33	35	38	41	43	44	46	48
0.8	13	16	19	22	26	29	32	35	38	42	45	46	48	51	54	57	60
0.9	17	20	24	28	32	35	39	43	47	51	53	57	60	64	68	71	75
1.0	20	24	29	33	38	42	47	51	56	61	63	68	72	77	81	86	90
1.1	23	28	34	39	44	49	54	60	65	70	74	79	84	89	95	100	105
1.2	28	33	40	45	51	58	64	69	76	80	86	92	98	104	110	116	122
1.3	32	38	46	53	58	65	73	80	86	91	99	106	112	119	125	133	140
1.4	37	44	51	59	66	74	82	90	96	103	111	119	127	134	142	150	158
1.5	41	50	58	66	75	85	92	101	108	116	125	133	142	150	160	169	178
1.6	46	56	65	75	84	94	104	112	122	132	142	149	158	168	178	187	197
1.7	52	62	72	83	94	105	115	126	135	145	156	167	175	187	196	206	217
1.8	58	69	81	93	104	116	127	138	150	160	171	182	194	204	214	226	233
1.9	64	76	88	102	114	127	140	152	164	175	188	201	213	225	235	248	260
2.0	71	83	97	111	125	138	153	164	178	193	204	218	232	245	256	269	283
2.1	77	91	107	122	135	149	162	177	192	207	220	234	250	267	276	291	305
2.2	84	100	116	131	146	163	177	194	210	224	238	253	269	288	301	314	330
2.3	90	108	124	140	158	175	193	208	226	243	258	275	292	306	323	341	354
2.4	99	116	136	152	170	189	206	224	241	260	275	294	312	327	346	364	378

Note: The side slopes cut for the emergency spillway must be no steeper than 2:1.

Operation and Maintenance:

A maintenance program shall be established to maintain the capacity and function of the sediment basin. Sediment basins shall be inspected on a weekly basis and after each runoff event. Necessary activities are shown as follows:

1. Establish vegetative cover and fertilize as necessary to maintain a vigorous cover in and around the sediment basin.
2. Remove undesirable vegetation periodically to prevent growth of trees and shrubs on the embankment and spillway areas.
3. Promptly repair eroded areas. Reestablish vegetative cover immediately where scour erosion has removed established seeding.
4. Promptly remove any burrowing rodents that may invade areas of the embankment.
5. Remove trash and debris that may block spillways and accumulate in the pond.
6. Remove sediment from basin when it fills the design depth of the sediment storage zone. This elevation shall be marked on a cleanout stake near the center of the basin.
7. Check spillway outlets and points of inflow to ensure drainage is not causing erosion and that outlets are not clogged. Replace displaced riprap immediately.
8. After the entire construction project is completed, temporary sediment basins should be dewatered and regraded to conform to the contours of the area. All temporary structures should be removed and the area seeded, mulched and stabilized as necessary.

References:

Barfield, B.J., R.C. Warner, and C.T. Haan. 1985. Applied Hydrology and Sedimentology for Disturbed Areas. Oklahoma Technical Press (Stillwater, OK).

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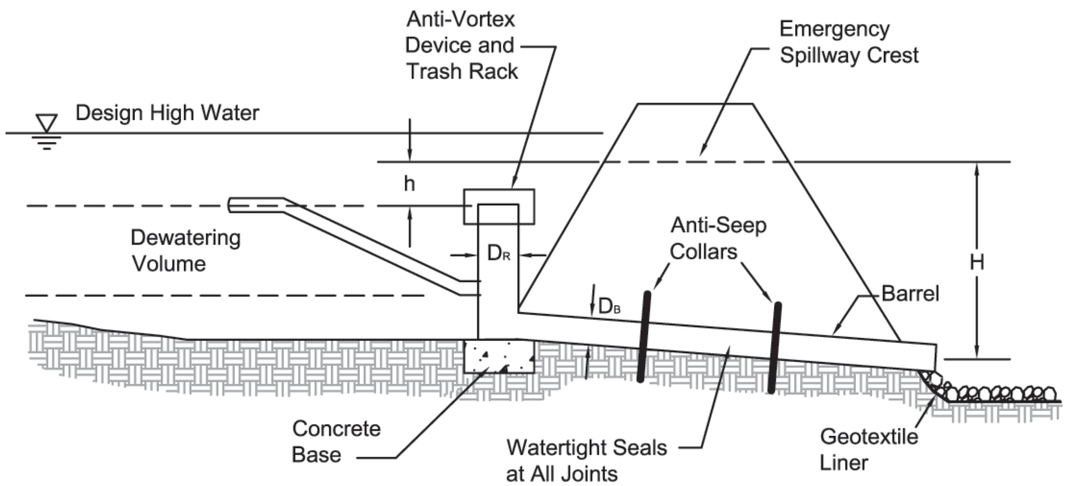
Specifications
for

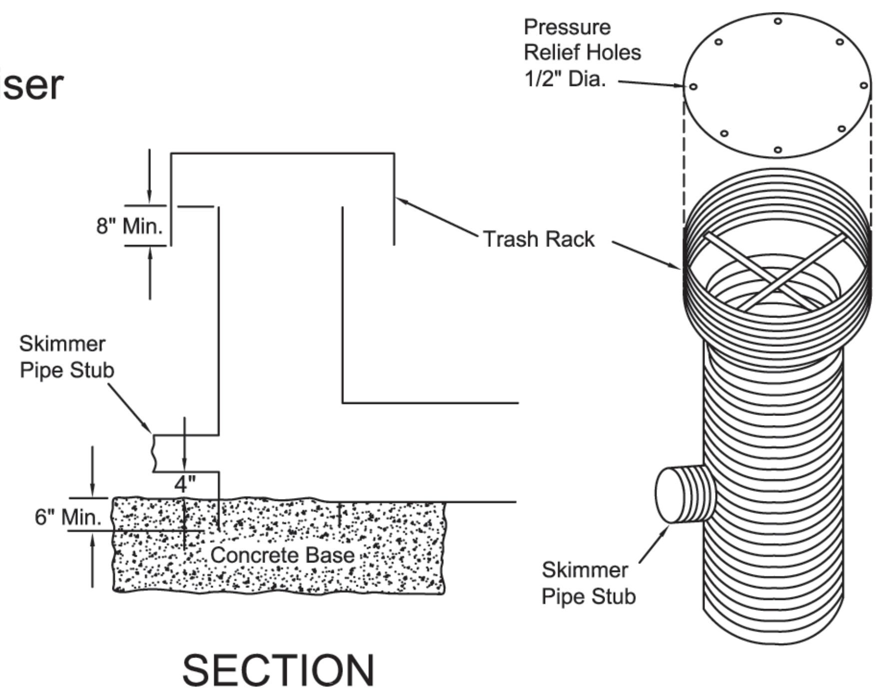
Sediment Basins



H = Head on Pipe through Embankment
h = Head above Riser Crest
D_B = Diameter of Barrel Pipe
D_R = Diameter of Riser

PROFILE
(Not to Scale)

Riser



SECTION
(Not to Scale)

Specifications
for

Sediment Basins

1. Sediment basins shall be constructed and operational before upslope land disturbance begins.
2. Site Preparation -The area under the embankment shall be cleared, grubbed, and stripped of any vegetation and root mat. The pool area shall be cleared as needed to facilitate sediment cleanout. Gullies and sharp breaks shall be sloped to no steeper than 1:1. The surface of the foundation area will be thoroughly scarified before placement of the embankment material.
3. Cut-Off Trench -The cutoff trench shall be excavated along the centerline of the embankment. The minimum depth shall be 3 ft. unless specified deeper on the plans or as a result of site conditions. The minimum bottom width shall be 4 ft., but wide enough to permit operation of compaction equipment. The trench shall be kept free of standing water during backfill operations.
4. Embankment -The fill material shall be free of all sod, roots, frozen soil, stones over 6 in. in diameter, and other objectionable material. The placing and spreading of the fill material shall be started at the lowest point of the foundation and the fill shall be brought up in approximately 6 in. horizontal layers or of such thickness that the required compaction can be obtained with the equipment used. Construction equipment shall be operated over each layer in a way that will result in the required compaction. Special equipment shall be used when the required compaction cannot be obtained without it. The moisture content of fill material shall be such that the required degree of compaction can be obtained with the equipment used.
5. Pipe Spillway -The pipe conduit barrel shall be placed on a firm foundation to the lines and grades shown on the plans. Connections between the riser and barrel, the anti-seep collars and barrel and all pipe joints shall be watertight. Selected backfill material shall be placed around the conduit in layers and each layer shall be compacted to at least the same density as the adjacent embankment. All compaction within 2 ft. of the pipe spillway will be accomplished with hand-operated tamping equipment.
6. Riser Pipe Base -The riser pipe shall be set a minimum of 6 in. in the concrete base.
7. Trash Racks -The top of the riser shall be fitted with trash racks firmly fastened to the riser pipe.
8. Emergency Spillway - The emergency spillway shall be cut in undisturbed ground. Accurate construction of the spillway elevation and width is critical and shall be within a tolerance of 0.2 ft.
9. Seed and Mulch -The sediment basin shall be stabilized immediately following its construction. In no case shall the embankment or emergency spillway remain bare for more than 7 days.
10. Sediment Cleanout -Sediment shall be removed and the sediment basin restored to its original dimensions when the sediment has filled one-half the pond's original depth or as indicated on the plans. Sediment removed from the basin shall be placed so that it will not erode.
11. Final removal - Sediment basins shall be removed after the upstream drainage area is stabilized or as indicated in the plans. Dewatering and removal shall NOT cause sediment to be discharged. The sediment basin site and sediment removed from the basin shall be stabilized.

6.2 Sediment Trap

Description

A sediment trap is a temporary settling pond formed by construction of an embankment and/or excavated basin and having a simple outlet structure that is typically stabilized with geotextile and rip-rap. Sediment traps are constructed to detain sediment-laden runoff from small, disturbed areas for a sufficient period of time to allow the majority of the sediment to settle out. They are established early in the construction process using natural drainage patterns and favorable topography where possible to minimize grading.

Conditions Where Practice Applies

Sediment traps are used:

1. At the outlets of diversions, channels, slope drains, or other runoff conveyances that discharge sediment–laden water.
2. Below disturbed areas where the total contributing drainage area is **5 acres or less**. If the contributing drainage area is greater than 5 acres, the use of a Sediment Basin is recommended.
3. Where access can be maintained for removal and proper disposal of sediment.
4. In drainage swales or areas, where sediment control is needed upstream of a drainage pattern leading to a storm drain inlet.
5. Where the required life of the structure will be 18 months or less.

6. Where failure of the structure will not result in loss of life; or cause damage to buildings, roads, utilities, or other properties.

Note: Sediment traps, that have the entire capacity achieved through excavation, may have larger drainage areas without compromising the stability of the sediment trap.

Planning Considerations

Timing – Sediment traps shall be constructed as a first step in any land-disturbing activity, and shall be made functional before upslope land disturbance takes place. Sediment traps are temporary measures with a typical design life of 6 months to 18 months. One or more traps are often built early in the construction process to capture sediment, prior to construction of a larger structure (e.g., sediment basin or modified detention basin) is constructed. Sediment traps are to be functional during the entire construction process, both before and after new drainage systems are constructed.

Location – Sediment traps usually are placed near the edges of construction sites so to be out of the way of major construction activities.

Diverting Runoff – Temporary diversions at the perimeter of sites are used to direct runoff to sediment traps (see Temporary Diversion Specifications).

Storm-Sewer Diversions – Storm drains may be temporarily redirected through sediment traps during construction. After construction, the temporary pipes are removed and runoff is allowed to flow through the permanent storm drain as originally intended.

Utilities – Give special consideration to sediment trap location and possible interference with construction of proposed drainage ways, utilities and storm drains.

Trapping Efficiency – Improved sediment trapping efficiencies can be achieved by including both a “wet” storage volume and a drawdown or “dry” storage volume that enhances settling and prevents excessive sediment losses during large storm events. In order to maintain effectiveness, sediment must be periodically removed from the trap to maintain the required design volume. Frequent inspection and appropriate maintenance should be provided until the construction site is permanently protected against erosion.

Design Criteria

Capacity - The minimum total design volume for the sediment trap shall consist of two components, the dewatering zone and the sediment storage zone. These zones are shown schematically in Figure 6.2.1. The volume of the dewatering zone shall be calculated for the entire drainage area by the method shown below. The drainage area includes the entire area contributing runoff to the sediment basin, offsite as well as on. The sediment storage volume may be in the form of a permanent pool or wet storage to provide a stable-settling medium, while the dewatered volume shall be in the form of a draw down or dry storage of at least 67 cubic yards per acre which will provide extended settling time during less frequent, larger storm events.

a) Dewatering Zone Volume –

The volume of the dewatering zone shall be a minimum of 1800 cubic feet per acre of drainage (67 yd3/acre) or the minimum stated in the current NPDES construction general permit. The total volume of the dewatering zone shall be measured from the base of the stone outlet structure to the crest of the stone outlet structure.

b) Sediment Storage Zone Volume –

The volume of the sediment storage zone shall be calculated by one of the following methods. The sediment storage zone shall be measured below the elevation of the base of the stone outlet structure.

Method 1: The volume of the sediment storage zone shall be 1000 cu. ft. per disturbed acre within the watershed of the basin; OR

Method 2: The volume of the sediment storage zone shall be the volume necessary to store the sediment yield as calculated with RUSLE or a similar generally accepted erosion prediction model. While the sediment storage volume may extend to the expected time period of the construction project, the minimum estimated time between cleanouts shall be six months.

Sediment shall be removed when it has accumulated to the top of the sediment storage or wet storage zone. This elevation shall be signified by the top of a stake near the center of the trap.

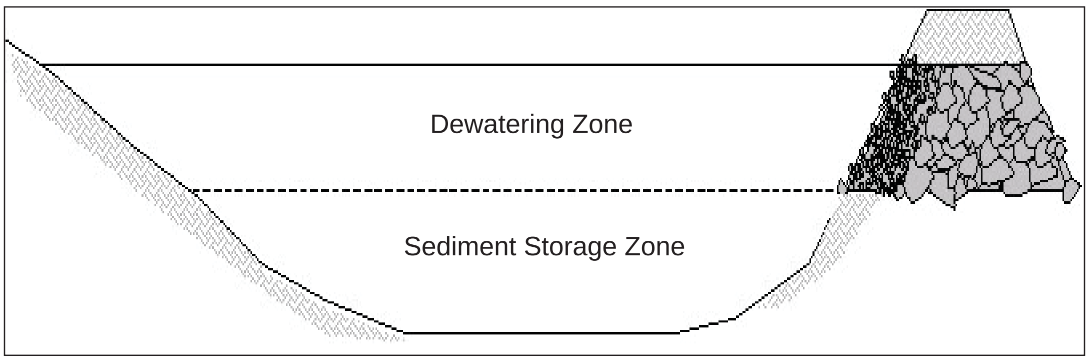


Figure 6.2.1 Capacity of a sediment trap is distributed between dewatering and sediment storage zones.

Embankment – Ensure that embankments for temporary sediment traps do not exceed 5 feet in height measured at the centerline from the original ground surface to the top of the embankment. Construct embankments with a minimum 4 foot top width and 2:1 (H:V) or flatter side slopes.

The design height of the embankment shall be increased by 5% to allow for settlement of the finished embankment. The original ground under the embankment shall be stripped of vegetation and scarified to a depth of 6 inches or more before placement of the fill material. Fill material should be made of clay, free of roots, large rocks, and organic material. Place fill in layers 6 inches thick and then compact using appropriate equipment. Fill material shall not be placed on frozen ground.

The completed embankment shall be seeded in accordance with temporary or permanent vegetation as found in this manual (Temporary Seeding or Permanent Seeding).

Excavation – Where sediment pools are formed or enlarged by excavation, keep side slopes at 2:1 (H: V) or flatter for safety. The maximum depth of excavation within the wet storage area (sediment storage zone) should be 4 feet to facilitate clean out and for site safety considerations.

Outlet Section – Construct the sediment trap outlet using a stone section of embankment located at the low point in the basin. The stone section serves two purposes: 1) the top section serves as a non-erosive spillway outlet for flood flow, and 2) the bottom section provides a means to de-watering the basin between runoff events. A combination of coarse aggregate and riprap shall be used to provide for filtering/detention as well as outlet stability.

Construct the outlet using well-graded stones with a d50 size larger than 6 inches (ODOT Type D). A 1 foot layer of AASHTO # 57 aggregate should be placed on the inside face to reduce drainage flow rate. Geotextile that meets the minimum requirements of ODOT Construction and Material Specification 712.09, Geotextile Fabric Type B, shall be placed at the stone-soil interface to act as a separation and to prevent piping. The geotextile shall be buried or keyed in at the upstream end a minimum of 6 inches. The crest of the stone outlet must be at least 1.5 feet below the top of the embankment to ensure that the flow will travel over the stone and not the embankment. The outlet shall be configured as noted in figure 2.

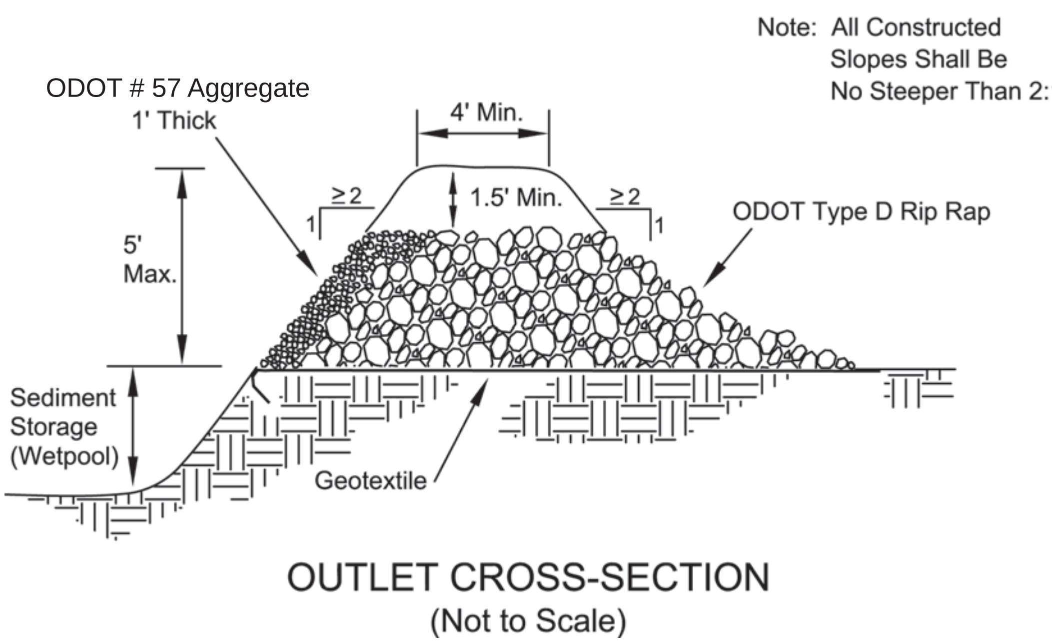


Figure 6.2.2 Outlet configuration

The spillway weir shall be at least 4 feet long and sized to pass the peak discharge of the 10-year, 24-hour storm without failure, overtopping of the basin or significant erosion. A maximum flow depth of 1 foot, a minimum freeboard of 0.5 foot, and maximum side slopes of 2:1 are required. See Table 6.2.1 for weir length associated with drainage area.

Table 6.2.1 Sediment Trap weir length.

Drainage Area (acres)	Weir Length (feet)
1	4.0
2	6.0
3	8.0
4	10.0
5	12.0

Note: alternatively use $Q_{weir} = CLH^{3/2}$
Where C = Weir coefficient
L = Weir Length (feet)
H = Head of 1 foot

Direct spillway discharges to natural, stable areas. Locate outlets so that flow will not damage the embankment. Discharges must be conveyed to a natural waterway via a channel of adequate capacity and stability. Where the channel enters a natural waterway, the discharge shall be less than 1 ½ feet per second or otherwise less than the velocity that will initiate erosion or scour within the receiving waterway. When traps discharge to storm water facilities, the facility must have adequate capacity to receive the discharge from the sediment trap.

Where an emergency spillway is utilized, the primary rock spillway crest should be at least 1.5 feet below the settled top of the embankment with the emergency spillway crest being 0.5 foot below the top of the embankment.

The plans and specifications should show the following requirements:

1. Location of the sediment traps.
2. Size of sediment trap including width, length and depth.
3. Minimum cross section of embankment.
4. Typical cross section through the spillway with geotextile fabric details and rock placement.
5. Location of emergency spillway, if used.
6. Gradation and quality of rock.
7. Plans shall detail how excavated sediment is to be disposed of, such as placement on areas where it will be stabilized or removal to an approved off-site location.

All plans should include the installation and maintenance schedules with the responsible party identified.

Install warning signs, barricades, perimeter fence and other measures around sediment traps as necessary to protect workers, children, equipment, etc.

Operation and Maintenance

1. The capacity and function of the sediment trap shall be maintained by inspecting on a weekly basis and after each runoff event, and by performing the necessary activities shown below.
2. Establish vegetative cover and fertilize as necessary to maintain a vigorous cover around the sediment trap.
3. Inspect the pool area, embankment and spillway area for burrowing rodents, slope failure, seepage, excess settlement, and displaced stone. The area should be inspected for structural soundness and repaired as needed.
4. Regularly inspect water discharged from trap for excess suspended sediments. Identify and perform necessary repairs to improve water quality. Excessive suspended sediments may require design modifications or treatment with flocculants.
5. Remove woody vegetated growth on the embankment and spillway areas.
6. Remove trash and debris that accumulate in the pond and have potential to block spillways.
7. Dewatering outlets shall be regularly checked to ensure that performance is maintained. Filter stone choked with sediment shall be removed and replaced to restore its flow capacity.
8. Remove sediment and restore the sediment trap to its original dimensions when sediment has accumulated to the top of the sediment storage or wet storage zone. This elevation shall be signified by the top of a stake near the center of the trap. Removing sediment by hand may be necessary adjacent to the outlet section of the embankment to prevent equipment damage. Place the removed sediment and stabilize with vegetation in a designated area where it will not easily erode again. Restore trap to its original dimensions and replace stone as needed on the outlet.
9. After the entire construction project is completed, temporary sediment traps should be dewatered and regraded so as to conform to the contours of the area. All temporary structures should be removed and the area seeded, mulched and stabilized as necessary.

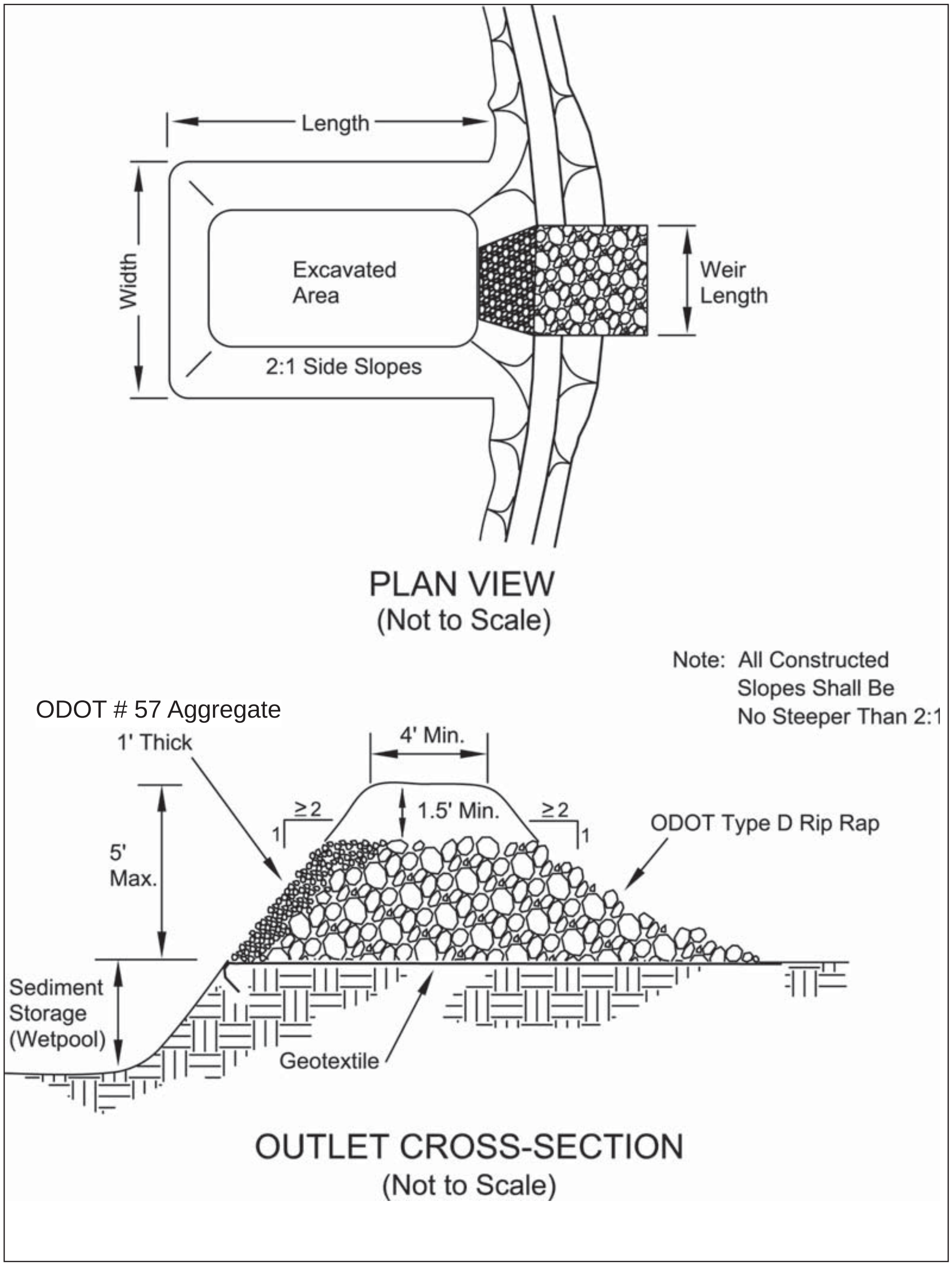
Common Problems/Concerns

Utilizing sediment traps on large drainage areas (greater than 5 acres) where Sediment Basins (see page 2 of this chapter) are appropriate will increase sediment discharged during construction.

Failure to removed trapped sediment will reduce the effectiveness of this practice in capturing sediment.

Specifications
for

Sediment Trap



Specifications
for

Sediment Traps

1. Work shall consist of the installation, maintenance and removal of all sediment traps at the locations designated on the drawings.
2. Sediment traps shall be constructed to the dimensions specified on the drawings and operational prior to upslope land disturbance.
3. The area beneath the embankment shall be cleared, grubbed and stripped of vegetation to a minimum depth of six (6) inches. The pool shall be cleared as needed to facilitate sediment cleanout.
4. Fill used for the embankment shall be evaluated to assure its suitability and it must be free of roots or other woody vegetation, large rocks, organics or other objectionable materials. Fill material shall be placed in six (6) inch lifts and shall be compacted by traversing with a sheepsfoot or other approved compaction equipment. Fill height shall be increased five (5) percent to allow for structure/foundation settlement. Construction shall not be permitted if either the earthfill or compaction surface is frozen.
5. The maximum height of embankment shall be five (5) feet. All cut and fill slopes shall be 2:1 (H:V) or flatter.
6. A minimum storage volume below the crest of the outlet of 67 yd^3. for every acre of contributing drainage area shall be achieved at each location noted on the drawings with additional sediment storage volume provided below this elevation.
7. Temporary seeding shall be established and maintained over the useful life of the practice.
8. The outlet for the sediment trap structure shall be constructed to the dimensions shown on the drawings.
9. The outlet shall be constructed using the materials specified on the drawings. Where geotextile is used, all overlaps shall be a minimum of two (2) feet or as specified by the manufacturer, whichever is greater. All overlaps shall be made with the upper most layer placed last. Geotextile shall be keyed in at least 6" on the upstream side of the outlet.
10. Warning signs and safety fence shall be placed around the traps and maintained over the life of the practice.
11. After all sediment-producing areas have been permanently stabilized, the structure and all associated sediment shall be removed. Stabile earth materials shall be placed in the sediment trap area and compacted. The area shall be graded to blend in with adjoining land surfaces and have positive drainage. The area shall be immediately seeded.

6.3 Silt Fence

Description

Silt fence is a sediment-trapping practice utilizing a geotextile fence, topography and sometimes vegetation to cause sediment deposition. Silt fence reduces runoff's ability to transport sediment by ponding runoff and dissipating small rills of concentrated flow into uniform sheet flow. Silt fence is used to prevent sediment-laden sheet runoff from entering into downstream creeks and sewer systems.

Conditions Where Practice applies

Silt fence is used where runoff occurs as sheet flow or where flow through small rills can be converted to sheet flow. Major factors in its use are slope, slope length, and the amount of drainage area from which the fence will capture runoff. Silt fence cannot effectively treat flows in gullies, ditches or channels. For concentrated flow conditions see specifications for temporary diversions, sediment traps and sediment basins.

Planning Considerations

Alternatives: Silt Fence vs. Temporary Diversions and Settling Ponds. While silt fence requires less space and disturbs less area than other control measures there are significant disadvantages to its use. Silt fence is not as effective controlling sediment as routing runoff through a system of diversions and settling ponds. Settling ponds and earth diversions are more durable, easier to construct correctly and significantly more effective at removing sediments from runoff. Additionally earth diversions and settling ponds are less apt to fail during construction and typically require less repair and maintenance.

Proper installation is critical. Experience from ODNR and other field testing has shown that nearly 75 percent of silt fence does not function properly due to poor installation. Proper installation consists of it being installed: (1) on the contour; (2) with sufficient geotextile material buried; (3) with the fence pulled taut and supported on the downstream side by strong posts: (4) and with the fence backfilled and compacted.

Two general methods are used to install silt fence: (1) utilizing traditional method of digging the trench, installation of the fence materials, then backfilling and compaction; or (2) a method using an implement to static slice or narrow plow while installing the geotextile in the slot opening, followed by compaction and installation of posts. The latter methods generally installs silt fence more effectively and efficiently.

Silt fence is most applicable for relatively small areas with flat topography. Silt fence should be used below areas where erosion will occur in the form of sheet and rill erosion. For moderately steep areas, the area draining to the silt fence should be no larger that one quarter acre per 100 feet of fence length, the slope length no longer than 100 feet, and the maximum drainage gradient no steeper than 50 percent (2:1). This practice should be sited so that the entire fence ponds runoff and facilitates settling of suspended solids.

Design Criteria

Proper installation of silt fence requires utilizing the site topography. This is critical because the sediment removal process relies on ponding runoff behind the fence. As a ponding occurs behind the fence, coarser materials are allowed to settle out. Leaving a long, flat slope behind the silt fence maximizes areas for ponding (sediment deposition), and for water to disperse and flow over a much larger surface area of the silt fence. For silt fence to work effectively, runoff must be allowed to maintain sheet flow, to pond and to be released slowly. However, if silt fence is used without regard to a site's topography, it will typically concentrate runoff, increasing the likelihood of blocking and overtopping of the fence, thus reducing or eliminating its effectiveness.

Level Contour – For silt fence to promote deposition, it must be placed on the level contour of the land, so that flows are dissipated into uniform sheet flow that has less energy for transporting sediment. Silt fence should never concentrate runoff, which will result if it is placed up and down slopes rather than on the level contour.

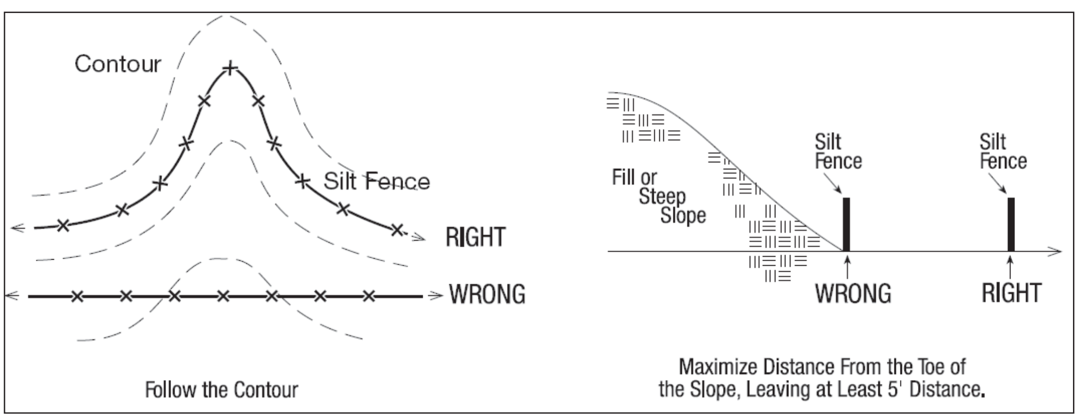


Figure 6.3.1 Silt fence layout

Flat Slopes – Slope has the greatest influence on runoff's ability to transport sediment, therefore silt fence should be placed several feet away from the toe of a slope if at all possible, to encourage deposition. Silt fence generally should be placed on the flattest area available to increase the shallow ponding of runoff and maximize space available for deposited sediment.

Flow Around Ends – To prevent water ponded by the silt fence from flowing around the ends, each end must be constructed upslope so that the ends are at a higher elevation.

Vegetation – Dense vegetation also has the effect of dissipating flow energies and causing sediment deposition. Sediment-trapping efficiency will be enhanced where a dense stand of vegetation occurs for several feet both behind and in front of a silt fence.

Table 6.3.1 Maximum area contributing area using slope length

Maximum Slope Length Above Silt Fence		
Slope		**Slope Length (ft.)**
0% - 2%	Flatter than 50:1	250
2% - 10%	50:1 - 10:1	125
10% - 20%	10:1 - 5:1	100
20% - 33%	5:1 - 3:1	75
33% - 50%	3:1 - 2:1	50
> 50%	> 2:1	25

Note: For larger drainage areas, see standards for temporary diversions, sediment traps and sediment basins.

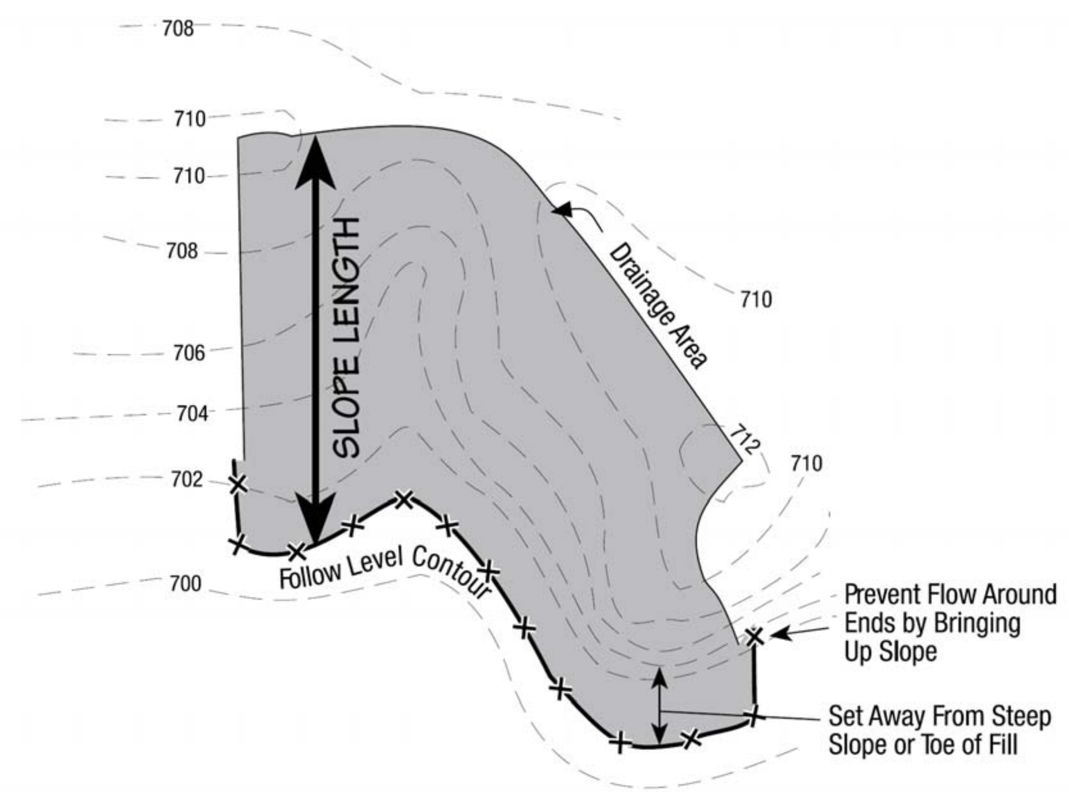


Figure 6.3.2 Silt fence and allowable drainage area

Dispersing Flow – Proper applications of silt fence allow all the intercepted runoff to pass as diffused flow through the geotextile. Runoff should never overtop silt fence, flow around the ends, or in any other way flow as concentrated flow from the practice. If any of these failures occurs, an alternative silt fence layout, or other practices are needed.

In cases where additional support of the fabric is needed, either wire or geogrid fencing may be used as a backing on the fabric. In these instances, the reinforcing material should be attached/erected first, then the fabric installed.

Materials

Fence posts shall be a minimum length of 32 inches long, composed of nominal dimensioned 2-by-2-inch hardwood of sound quality. They shall be free of knots, splits and other visible imperfections which would weaken the posts. Steel posts may be utilized in place of wood provide the geotextile can be adequately secured to the post.

Silt fence geotextile must meet the minimum criteria shown in the table below.

Table 6.3.2

Minimum criteria for Silt Fence Fabric (ODOT, 2002)		
Minimum Tensile Strength	120 lbs. (535 N)	ASTM D 4632
Maximum Elongation at 60 lbs	50%	ASTM D 4632
Minimum Puncture Strength	50 lbs (220 N)	ASTM D 4833
Minimum Tear Strength	40 lbs (180 N)	ASTM D 4533
Apparent Opening Size	≤ 0.84 mm	ASTM D 4751
Minimum Permittivity	$1X10^{-2}$ sec.$^{-1}$	ASTM D 4491
UV Exposure Strength Retention	70%	ASTM G 4355

Maintenance

Silt Fence requires regular inspection and maintenance to insure its effectiveness. Silt fences must be inspected after each rainfall and at least daily during prolonged rainfall. Silt fence found damaged or improperly installed shall be replaced or repaired immediately.

Sediment deposits shall be routinely removed when they reach approximately one-half the height of the silt fence.

Common Problems/Concerns

The predominant problems with silt fence regard inadequate installation or location that allows runoff to concentrate, overtop the fence, flow under the fabric or around the fence ends. If this occurs one of the following shall be performed, as appropriate:

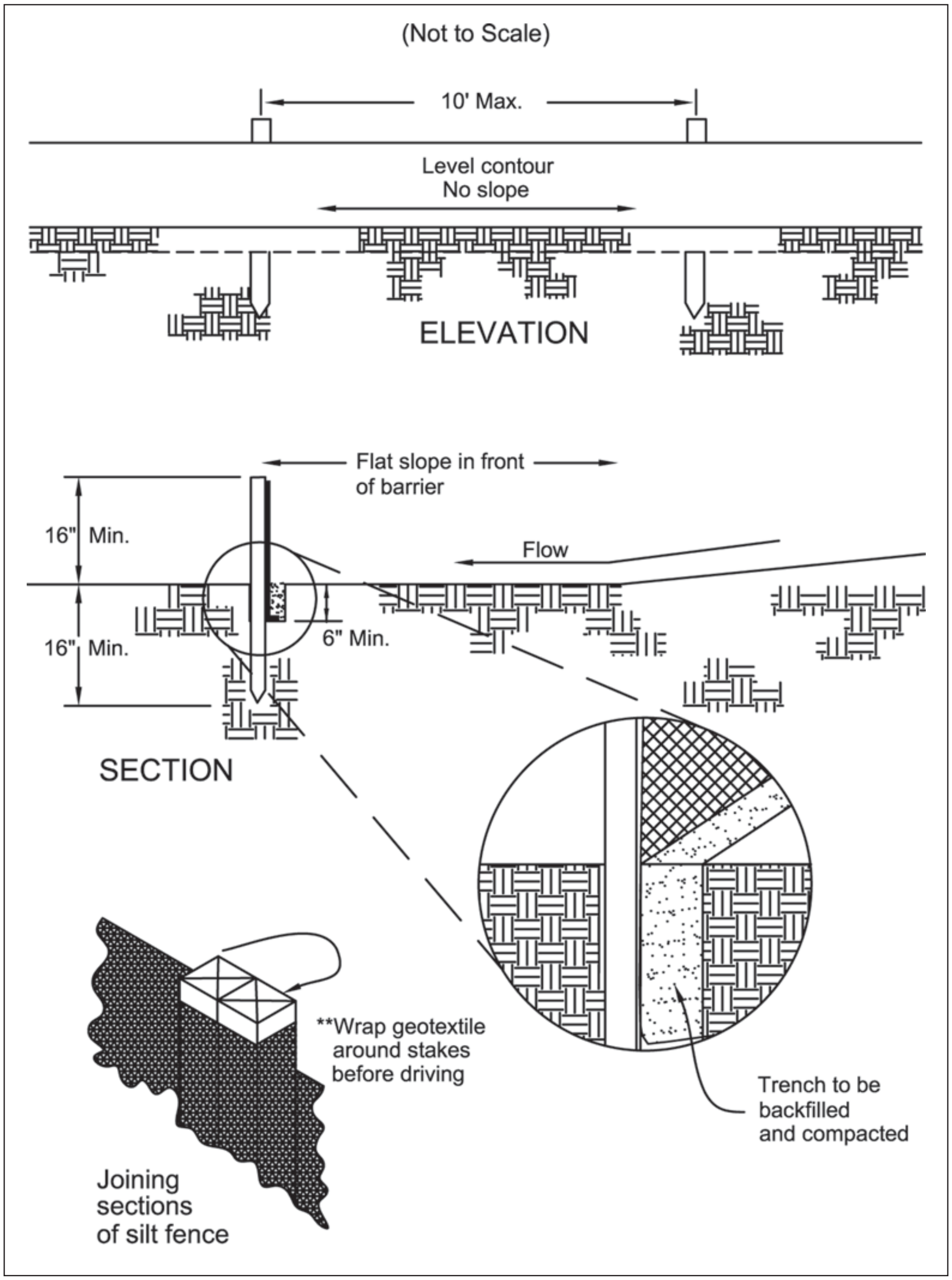
- The location and layout of the silt fence shall be changed to conform to the level contour
- The silt fence shall be reinstalled with proper burial, backfill and compaction and support
- Accumulated sediment shall be removed
- Alternative practices shall be installed.

References

Construction and Material Specifications, January 1, 2002. State of Ohio Department of Transportation, P.O. Box 899, Columbus, Ohio 43216-0899, http://www.dot.state.oh.us/construction/OCA/Specs/2002CMS/Specbook2002/Specbook2002.htm

Specifications
for

Silt Fence



Specifications
for

Silt Fence

1. Silt fence shall be constructed before upslope land disturbance begins.
2. All silt fence shall be placed as close to the contour as possible so that water will not concentrate at low points in the fence and so that small swales or depressions that may carry small concentrated flows to the silt fence are dissipated along its length.
3. Ends of the silt fences shall be brought upslope slightly so that water ponded by the silt fence will be prevented from flowing around the ends.
4. Silt fence shall be placed on the flattest area available.
5. Where possible, vegetation shall be preserved for 5 feet (or as much as possible) upslope from the silt fence. If vegetation is removed, it shall be reestablished within 7 days from the installation of the silt fence.
6. The height of the silt fence shall be a minimum of 16 inches above the original ground surface.
7. The silt fence shall be placed in an excavated or sliced trench cut a minimum of 6 inches deep. The trench shall be made with a trencher, cable laying machine, slicing machine, or other suitable device that will ensure an adequately uniform trench depth.
8. The silt fence shall be placed with the stakes on the downslope side of the geotextile. A minimum of 8 inches of geotextile must be below the ground surface. Excess material shall lay on the bottom of the 6-inch deep trench. The trench shall be backfilled and compacted on both sides of the fabric.
9. Seams between sections of silt fence shall be spliced together only at a support post with a minimum 6-in. overlap prior to driving into the ground, (see details).
10. Maintenance—Silt fence shall allow runoff to pass only as diffuse flow through the geotextile. If runoff overtops the silt fence, flows under the fabric or around the fence ends, or in any other way allows a concentrated flow discharge, one of the following shall be performed, as appropriate: 1) the layout of the silt fence shall be changed, 2) accumulated sediment shall be removed, or 3) other practices shall be installed.

    Sediment deposits shall be routinely removed when the deposit reaches approximately one-half of the height of the silt fence.

    Silt fences shall be inspected after each rainfall and at least daily during a prolonged rainfall. The location of existing silt fence shall be reviewed daily to ensure its proper location and effectiveness. If damaged, the silt fence shall be repaired immediately.

Criteria for silt fence materials

1. Fence post – The length shall be a minimum of 32 inches. Wood posts will be 2-by-2-in. nominal dimensioned hardwood of sound quality. They shall be free of knots, splits and other visible imperfections, that will weaken the posts. The maximum spacing between posts shall be 10 ft. Posts shall be driven a minimum 16 inches into the ground, where possible. If not possible, the posts shall be adequately secured to prevent overturning of the fence due to sediment/water loading.
2. Silt fence fabric – See chart below.

Table 6.3.2 **Minimum criteria for Silt Fence Fabric (ODOT, 2002)**

FABRIC PROPERTIES	VALUES	TEST METHOD
Minimum Tensile Strength	120 lbs. (535 N)	ASTM D 4632
Maximum Elongation at 60 lbs	50%	ASTM D 4632
Minimum Puncture Strength	50 lbs (220 N)	ASTM D 4833
Minimum Tear Strength	40 lbs (180 N)	ASTM D 4533
Apparent Opening Size	≤ 0.84 mm	ASTM D 4751
Minimum Permittivity	1X10-2 sec.-1	ASTM D 4491
UV Exposure Strength Retention	70%	ASTM G 4355

6.4 Storm Drain Inlet Protection

Description

Storm drain inlet protection devices remove sediment from storm water before it enters storm sewers and downstream areas. Inlet protection devices are sediment barriers that may be constructed of washed gravel or crushed stone, geotextile fabrics and other materials that are supported around or across storm drain inlets.

Inlet protection is installed to capture some sediment and reduce the maintenance of storm sewers and other underground piping systems prior to the site being stabilized. Due to their poorer effectiveness, inlet protection is considered a secondary sediment control to be used in conjunction with other more effective controls.

Condition Where Practice Applies

Storm drain inlet protection is applicable anywhere construction site runoff may enter closed conveyance systems through storm sewer inlets. Generally inlet protection is limited to areas draining less than 1 acre.

This practice is generally not recommended as a primary means of sediment control. Storm drain inlet protection has limited capacity to control silts and clays, and is most effective in capturing larger sand-sized particles. It should only be a primary means if it is not possible to divert the storm drainage to a sediment trap or sediment basin, or if it is to be used only for a short period of time during the construction process.

Planning Considerations

Inlet protection in effect blocks storm drain inlets. Therefore consider the effect of ponding muddy water on streets and nearby areas and plan accordingly. Although ponding is beneficial in the sediment removal process, this may pose hazardous conditions for street travel. Additional ponding capacity with related increase in effectiveness can be provided for some drop inlets by excavating around the inlet.

Utilizing inlet protection on long sloping streets may cause runoff to bypass inlets on the slope and cause extra water to accumulate in low areas. In order for the inlet protection to work ponding must be maintained at the practice.

The recommended geotextiles are suitable for retaining/trapping large particle size materials, such as sand while maintaining some flow. Only specialized geotextile materials are suitable for retaining clay, silt and other fine soils. These materials, however, are subject to clogging.

Apply storm drain inlet protection as soon as the surface inlet is capable of receiving storm water. Geotextiles utilized in inlet protection are manufactured to control the rate of storm water flow, to retain certain sizes of soil particles. The controlled flow and ponding assists in sediment deposition. Geotextile fabrics come in a variety of materials with permeability, strength and durability ratings. In all cases, follow the manufacturer's recommendations for the specific product application, as well as installation and maintenance requirements.

All inlet protection practices require frequent maintenance and cleaning to maintain sufficient flow rates and to prevent accumulation of mud on streets and other areas.

The following types of storm drain inlet protection are listed according to type of flows and situations where they will perform best. Note that straw bales are not suitable as storm drain inlet protection, since they are often cease to allow flow through once saturated and often leak where bales join. Different types of storm drain inlet protection available are as follows:

A. Excavated Drop Inlet Sediment Trap. Where the storm sewer can be left below the final grade, a depression in the ground adjacent to the inlet can be an effective way of reducing sediment going to the storm sewer. Runoff is directed to the depression and a sediment barrier is maintained between the depression and the storm sewer.

B. Geotextile Inlet Protection. This method consists of placing filter fence around the perimeter of the drop inlet and backfilling. Apply this method where the inlet drains overload flow or sheet flow from gentle slopes and sheet or overland flow.

C. Geotextile-Stone Protection. These are used both on drop inlets and in street curbs and gutters where the ponding of water will not cause damage or inconvience. This filter is simply constructed of geotextile materials over the inlet, with stone on top. Note: this practices does not have an opening for overflow and should not be placed where clogging and subsequent flooding would cause safety concerns or property damage.

D. Geotextile-Stone Curb Inlet Protection. This method is used only on curb and gutter inlets and utilizes wire mesh, geotextile and stone over a wood frame. This practice should be used to prevent larger volumes of water from ponding in the street. If the overflow provided is insufficient, it may be modified according to this specification to accommodate greater flows.

E. Block and Gravel Drop Inlet Protection. This practice utilizes a wall of cement blocks overlain with wire mesh and gravel around the perimeter to slow runoff before entering a storm drain. It is not recommended anywhere vehicle traffic will be operating.

F. Manufactured Inlet Protection Devices. Any manufactured products utilized for inlet protection must be constructed of materials equally durable and effective as those provided in this practice. They must be able to be secured such that construction site runoff is intercepted, ponded and filtered prior to entering the storm drain except during extreme flows. Devices must allow the removal of captured material without falling into the catch basin.

Maintenance

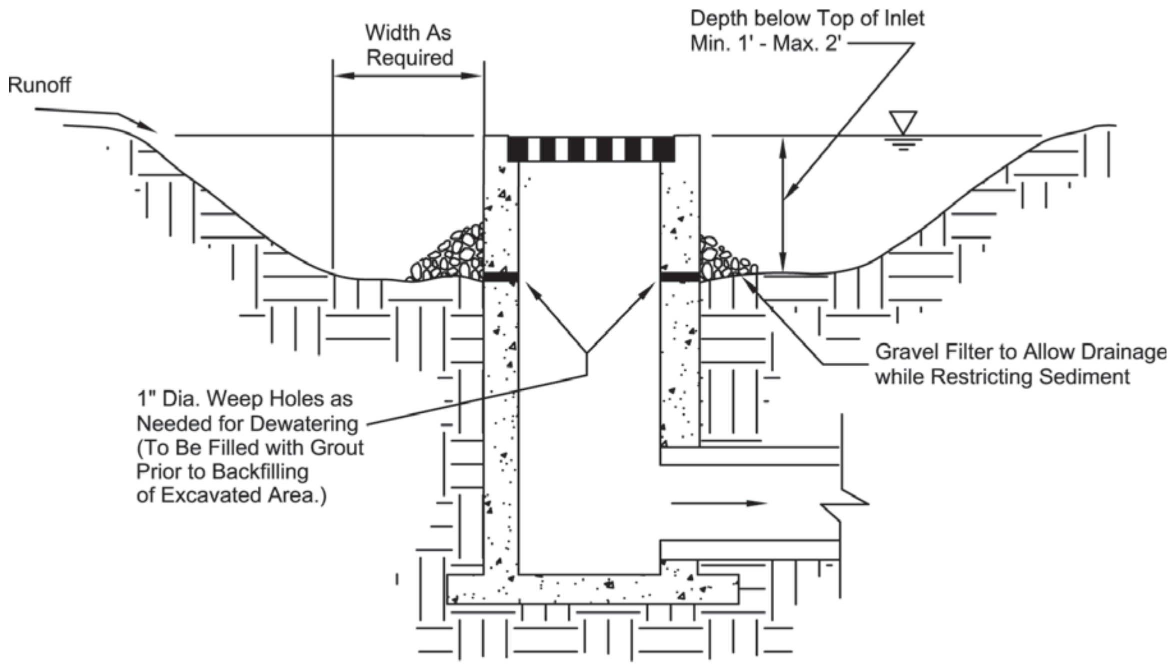
Effective storm drain inlet protection collects sediment and therefore must be cleaned regularly to prevent clogging and subsequent flooding conditions, piping, or overtopping of the control structures. Sediment barriers that sag, fall over, or are not properly secured, must be promptly repaired or replaced.

Inlet protection shall be inspected weekly and after each rainfall event. Areas where there is active traffic shall be inspected daily. Repairs shall be made as needed to assure the practice is performing as intended. Sediment shall be removed when accumulation is one-half the height of the trap. Sediment shall not be washed into the inlet. Sediment shall be removed and placed in a location where it is stable and not subject to erosion.

Once the contributing drainage area has been properly stabilized, all filter material and collected sediment shall be removed and properly disposed.

Specifications
for

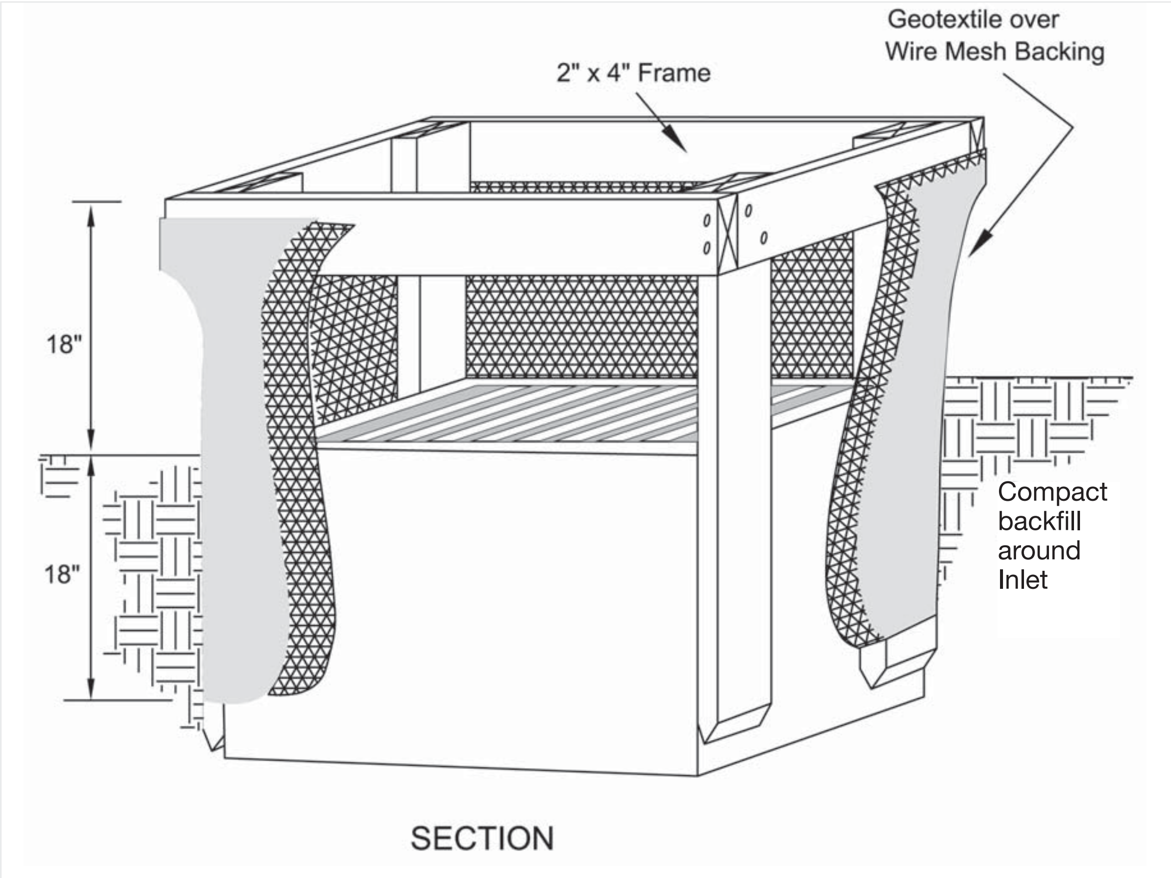
Excavated Drop Inlet Sediment Protection



SECTION
(Not to Scale)

1. The excavated trap should be sized to provide a minimum storage capacity calculated at the rate of 135 cubic yards for one (1) acre of drainage area. A trap should be no less than one (1) foot, nor more than two (2) feet deep measured from the top of the inlet structure. Side slopes should not be steeper than 2:1.
2. The slopes of the trap may vary to fit the drainage area and terrain.
3. Where the area receives concentrated flows, such as in a highway median, provide the trap with a shape having a 2:1 ratio of length to width, with the length oriented in the direction of the flow.
4. Sediment should be removed and the trap restored to the original depth when the sediment has accumulated to 40% the design depth of the trap. Removed sediment should be spread in a suitable area and stabilized so it will not erode.
5. During final grading, the inlet should be protected with geotextile-stone inlet protection. Once final grading is achieved, sod or a suitable temporary erosion control material shall be implemented to protect the area until permanent vegetation is established.

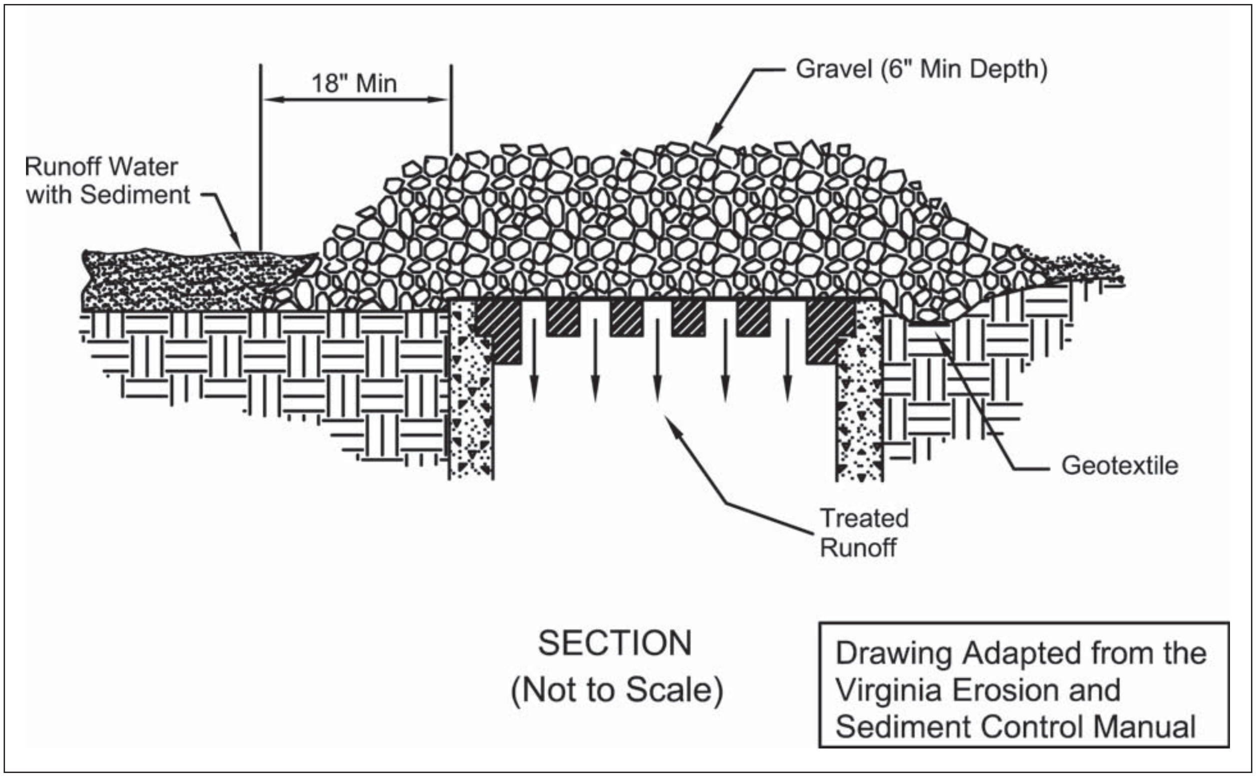
Specifications
for
Geotextile Inlet Protection



1. Inlet protection shall be constructed either before upslope land disturbance begins or before the inlet becomes functional.
2. The earth around the inlet shall be excavated completely to a depth at least 18 inches.
3. The wooden frame shall be constructed of 2-inch by 4-inch construction grade lumber. The 2-inch by 4-inch posts shall be driven one (1) ft. into the ground at four corners of the inlet and the top portion of 2-inch by 4-inch frame assembled using the overlap joint shown. The top of the frame shall be at least 6 inches below adjacent roads if ponded water will pose a safety hazard to traffic.
4. Wire mesh shall be of sufficient strength to support fabric with water fully impounded against it. It shall be stretched tightly around the frame and fastened securely to the frame.
5. Geotextile material shall have an equivalent opening size of 20-40 sieve and be resistant to sunlight. It shall be stretched tightly around the frame and fastened securely. It shall extend from the top of the frame to 18 inches below the inlet notch elevation. The geotextile shall overlap across one side of the inlet so the ends of the cloth are not fastened to the same post.
6. Backfill shall be placed around the inlet in compacted 6-inch layers until the earth is even with notch elevation on ends and top elevation on sides.
7. A compacted earth dike or check dam shall be constructed in the ditch line below the inlet if the inlet is not in a depression. The top of the dike shall be at least 6 inches higher than the top of the frame.

Specifications
for

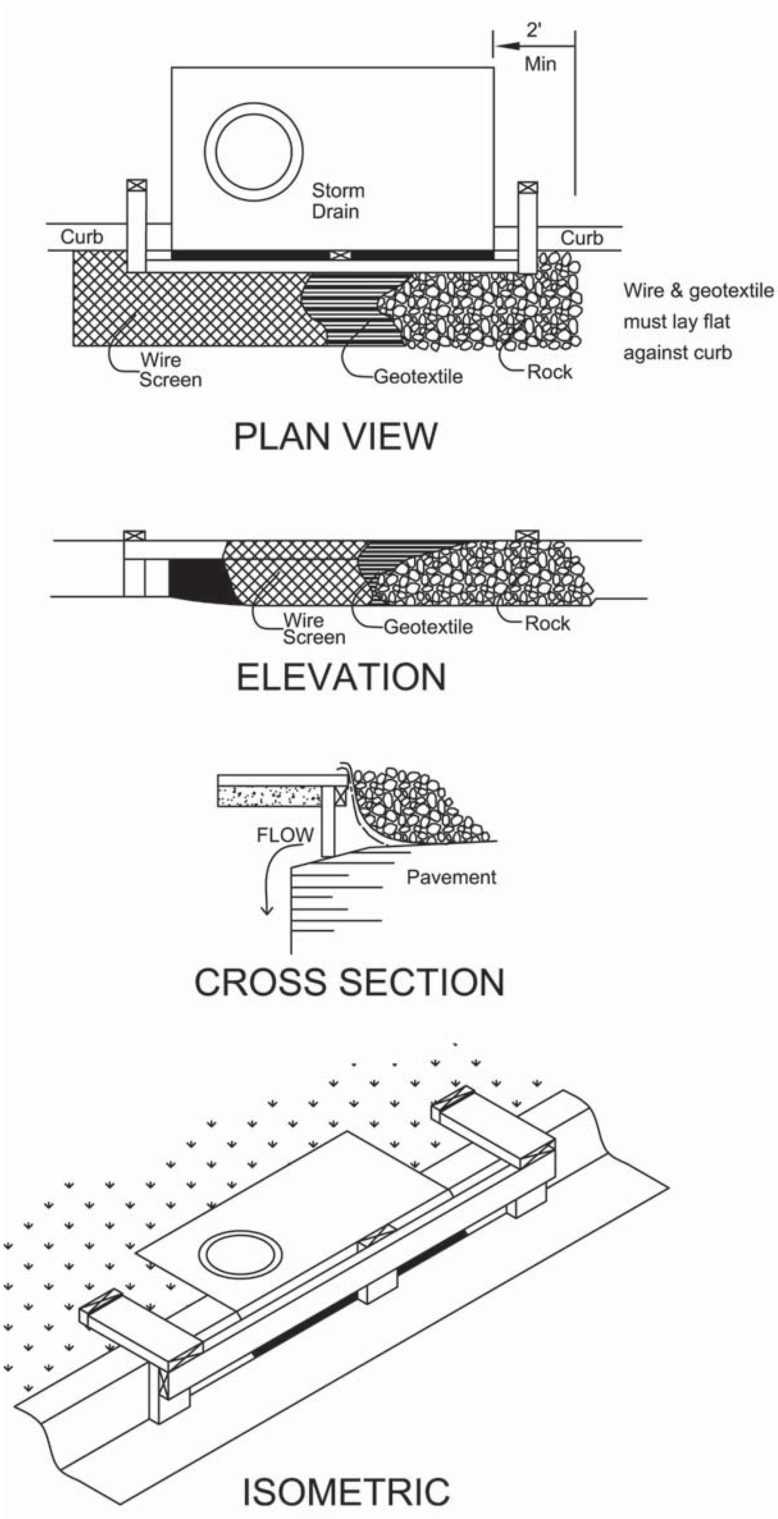
Geotextile-Stone Inlet Protection



1. Inlet protecion shall be constructed either before upslope land disturbance begins or before the inlet becomes functional.
2. Geotextile and/or wire material shall be placed over the top of the storm sewer and approximately six (6) inches of 2-inch or smaller clean aggregate placed on top. Extra support for geotextile is provided by placing hardware cloth or wire mesh across the inlet cover. The wire should be no larger than ½" mesh and should extend an extra 12 inches across the top and sides of the inlet cover.
3. Maintenance must be performed regularly, especially after storm events. When clogging of the stone or geotextile occurs, the material must be removed and replaced.

Specifications
for

Geotextile - Stone Inlet Protection for Curb Inlets



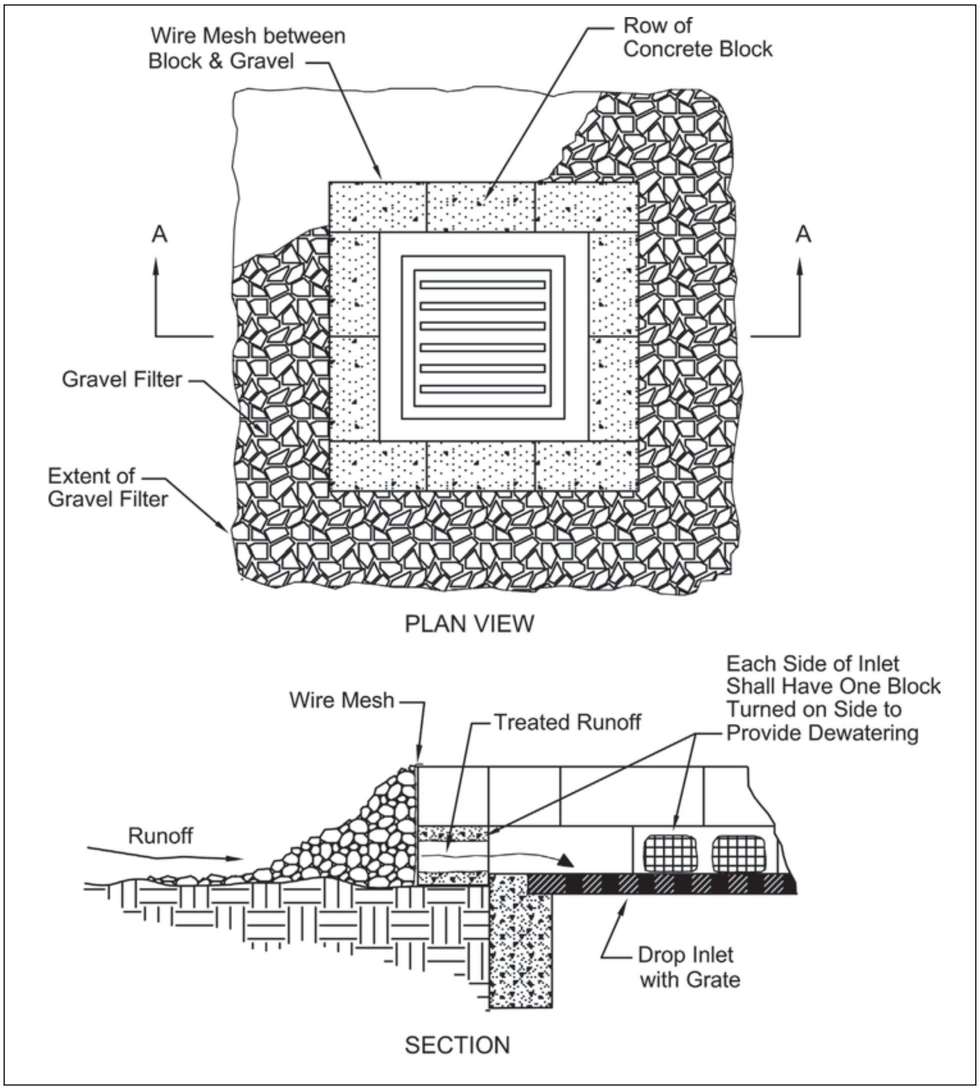
Specifications
for

Geotextile-Stone Inlet Protection for Curb Inlets

1. Inlet protection shall be constructed either before upslope land disturbance begins or before the inlet becomes functional.
2. Construct a wooden frame of 2-by-4-in. construction-grade lumber. The end spacers shall be a minimum of 1 ft. beyond both ends of the throat opening. The anchors shall be nailed to 2-by-4-in. stakes driven on the opposite side of the curb.
3. The wire mesh shall be of sufficient strength to support fabric and stone. It shall be a continuous piece with a minimum width of 30 in. and 4 ft. longer than the throat length of the inlet, 2 ft. on each side.
4. Geotextile cloth shall have an equivalent opening size (EOS) of 20-40 sieve and be resistant to sunlight. It shall be at least the same size as the wire mesh.
5. The wire mesh and geotextile cloth shall be formed to the concrete gutter and against the face of the curb on both sides of the inlet and securely fastened to the 2-by-4-in. frame.
6. Two-inch stone shall be placed over the wire mesh and geotextile in such a manner as to prevent water from entering the inlet under or around the geotextile cloth.
7. This type of protection must be inspected frequently and the stone and/or geotextile replaced when clogged with sediment.

Specifications
for

Block and Gravel Drop Inlet Filter



1. Place 4-inch by 8-inch by 12-inch concrete blocks lengthwise on their sides in a single row around the perimeter of the inlet, with the ends of adjacent blocks abutting. The height of the barrier can be varied, depending upon the design needs, by stacking combinations of the same size blocks. The barrier of blocks should be at least 12-inches high but no greater than 24-inches high.
2. Wire mesh should be placed over the outside vertical face (webbing) of the concrete blocks to prevent stone from being washed through the block cores. Hardware cloth or comparable wire mesh with ½-inch openings should be used.
3. Two-inch stone should be piled against the wire to the top of the block barrier, as shown below.
4. If the stone filter becomes clogged with sediment so that it no longer adequately performs its function, pull stone away from the blocks, clean and/or replace.

6.5 Filter Berm

Description

Filter berms are sediment trapping practices that utilize a compost/mulch material. They are typically installed with pneumatic equipment. Filter berms reduce sediment from runoff by slowing and filtering runoff, and dissipating flow.

Conditions Where Practice Applies

Filter berms are appropriate on nearly level ground or slopes up to 5:1, where runoff occurs as sheet flow. Filter berms cannot effectively treat flows in gullies, ditches or channels. For more severe conditions see specifications for temporary diversions, sediment traps, and sediment basins.

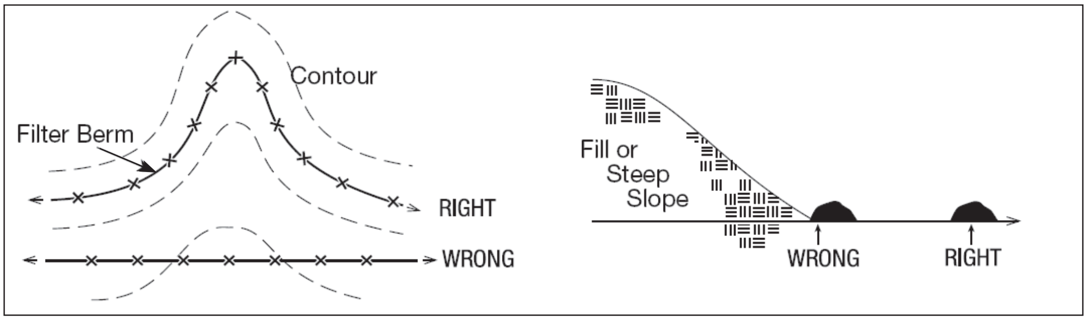
Design Criteria

Compost filter berms used as sediment control practice require an adequately constructed berm constructed on the contour, that is, on a level line across the site's topography. While silt fences rely primarily on settling, compost filter berms filter runoff as it passes through the practice. To accomplish this, runoff must be intercepted on the contour to insure that sheet flow is not concentrated into rills or channels.

Materials – Compost/mulch used for filter berms shall be weed free and derived from a well-decomposed source of organic matter. The compost shall be produced using an aerobic composting process meeting CFR 503 regulations, including time and temperature data indicating effective weed seed, pathogen and insect larvae kill. The compost shall be free of any refuse, contaminants or other materials toxic to plant growth.

Materials should meet the following requirements: pH between 5.0-8.0; 100% passing a 3" sieve, 90% to 100% passing a 1" sieve, 70% to 100% passing a 3/4", no more than 50% shall pass a 1/4" sieve; moisture content is less than 60%; material shall be relatively free (<1% by dry weight) of inert or foreign man made materials.

Level Contour – Filter berms must be placed on the level contour of the land so that flows are dissipated into uniform sheet flow that has less energy for transporting sediment. Filter berms should never concentrate runoff, which will occur if it is placed up and down slopes rather than on the level contour.



Flat Slopes – If at all possible, filter berms should be placed away from the toe of a slope and on the flattest area available. This allows the sheet flow energy to dissipate and allows for a greater storage area for sediments.

Steeper Slopes – For placement on steeper slopes follow the spacing recommendations on the following table.

Drainage Area – Follow recommendations on following table

Table 6.5.1 Filter Berm Spacing for General Applications *Install Parallel Along Contours As Follows		
Ratio (H:V)	% Slope	Recommended Spacing
< 20:1	5% or less	300 foot with a maximum of 1 acre per 500 lineal feet
20:1 - 10:1	5 to 10%	75 foot intervals
9:1 - 5:1	10 to 20%	50 foot intervals

Flow Around Ends – To prevent water from flowing around the ends of the Filter berm each end must be constructed up-slope so that the ends are at a higher elevation.

Vegetation – Filter berm may be vegetated for a more permanent placement such as wetlands and natural areas.

References

Standard Specification for Compost for Erosion/Sediment Control (Filter Berms) http://www.iaasla.org/NEWS/FILES/AASHTO-Filterberm6.doc

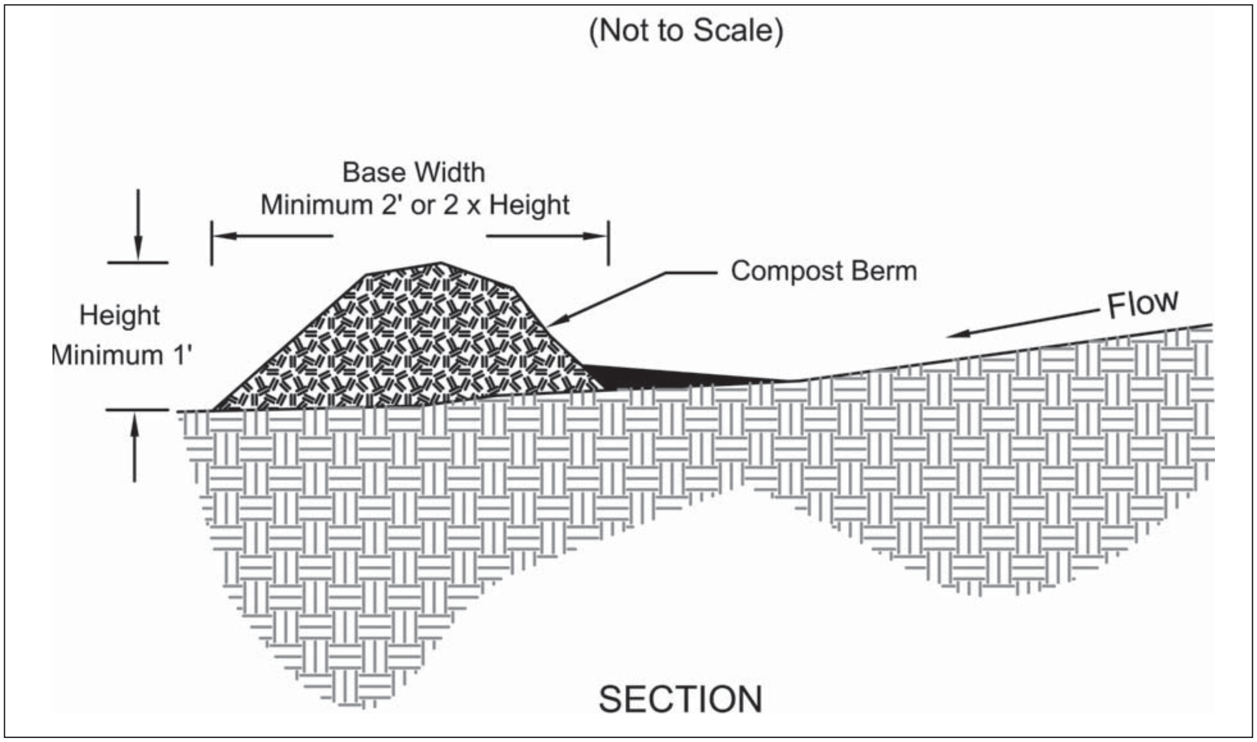
www.dot.state.pa.us/Penndot/Bureaus/ ChiefEng.nsf/spec%20filter%20berms?OpenPage - 28k

http://tammi.tamu.edu/erosion_control_fact_sheet.pdf Using compost for eroison controls and revegetation, S. Mukhtar Texas Cooperative Extension, The Texas A & M Universtiy System.Prepared in cooperation with the Texas Commission on Environmental Quality and the U.S. Environmental Protection Agency.

http://www.ces.uga.edu/pubcd/B1200.htm

Specifications
for

Filter Berm



1. Materials – Compost used for filter berms shall be weed, pathogen and insect free and free of any refuse, contaminants or other materials toxic to plant growth. They shall be derived from a well-decomposed source of organic matter and consist of a particles ranging from 1/4" to 3".
2. Installation – Filter berms will be placed on a level line across slopes, generally parallel to the base of the slope or other affected area. On slopes approaching 2:1, additional berms shall be provided at the top and as needed mid-slope.

   Filter berms are not to be used in concentrated flow situations or in runoff channels.
3. Maintenance – Inspect filter berms after each significant rain, maintaining the berms in a functional condition at all times.

   Remove sediments collected at the base of the filter berms when they reach 1/3 of the exposed height of the practice.

   Where the filter berm deteriorates or fails it will be, it will be repaired or replaced with a more effective alternative.
4. Removal – Filter berms no longer needed will be dispersed on site in a manner that will facilitate seeding.

6.6 Filter Sock

Description

Filter socks are sediment-trapping devices using compost inserted into a flexible, permeable tube with a pneumatic blower device or equivalent. Filter socks trap sediment by filtering water passing through the berm and allowing water to pond, creating a settling of solids.

Conditions where practice applies

Filter socks are appropriate for limited drainage areas, requiring sediment control where runoff is in the form of sheet flow or in areas that silt fence is normally considered acceptable. The use of filter socks is applicable to slopes up to 2:1 (H:V), around inlets, and in other disturbed areas of construction sites requiring sediment control. Filter socks also may be useful in areas, where migration of aquatic life such as turtles, salamanders and other aquatic life would be impeded by the use of silt fence.

Planning Considerations

Filter socks are sediment barriers, capturing sediment by ponding and filtering water through the device during rain events. They may be a preferred alternative where equipment may drive near or over sediment barriers, as they are not as prone to complete failure as silt fence if this occurs during construction. Driving over filter socks is not recommended; but if it should occur, the filter sock should be inspected immediately, repaired and moved back into place as soon as possible.

Design Criteria

Typically, filter socks can handle the same water flow or slightly more than silt fence. For most applications, standard silt fence is replaced with 12" diameter filter socks. However, proper installation is especially important for them to work effectively.

Materials – Compost/mulch used for filter socks shall be weed free and derived from a well-decomposed source of organic matter. The compost shall be produced using an aerobic composting process meeting CFR 503 regulations, including time and temperature data indicating effective weed seed, pathogen and insect larvae kill. The compost shall be free of any refuse, contaminants or other materials toxic to plant growth. Non-composted products are not acceptable.

Materials should meet the following requirements: pH between 5.0-8.0; 100% passing a 2" sieve and a minimum of 70% greater than the 3/8" sieve; moisture content is less than 60%; material shall be relatively free (<1% by dry weight) of inert or foreign man made materials.

Level Contour – Place filter socks on the level contour of the land so that flows are dissipated into uniform sheet flow. Flow coming to filter socks must not be concentrated and the filter sock should lie perpendicular to flows.

Flat Slopes – When possible, place filter socks at a 5' or greater distance away from the toe of the slopes in order for the water coming from the slopes to maximize space available for sediment deposit (see the illustration). When this is not possible due to construction limitations, additional filter socks may be required upslope of the initial filter sock (see the chart below for appropriate slope lengths and spacing).

Flow Around Ends – In order to prevent water flowing around the ends of filter socks, the ends of the filter socks must be constructed pointing upslope so the ends are at a higher elevation.

Vegetation – For permanent areas, seeding filter socks is recommended to establish vegetation directly in the sock and immediately in front and back of the sock at a distance of 5 feet. Vegetating on and around the filter socks will assist in slowing down water for filtration creating a more effective longer-term sediment control.

Drainage Area: Generally filter socks are limited to ¼ to ½ acre drainage area per 100 foot of the sediment barrier. Specific guidance is given in the chart below.

Table 6.6.1 Maximum Slope Length Above Filter Sock and Recommended Diameter

Slope	Ratio (H:V)	8"	12"	18"	24"
0% - 2%	10% - 20%	125	250	300	350
10% - 20%	50:1 - 10:1	100	125	200	250
2% - 10%	10:1 - 5:1	75	100	150	200
20% - 33%	5:1 - 2:1		50	75	100
>50%	>2:1		25	50	75

Note: For larger drainage areas, see standards for temporary diversions, sediment traps and sediment basins.

Dispersing flow – Sheet flow and runoff should not exceed berm height or capacity in most storm events. If overflow of the berm is a possibility, a larger filter sock should be installed or an alternative sediment control should be used.

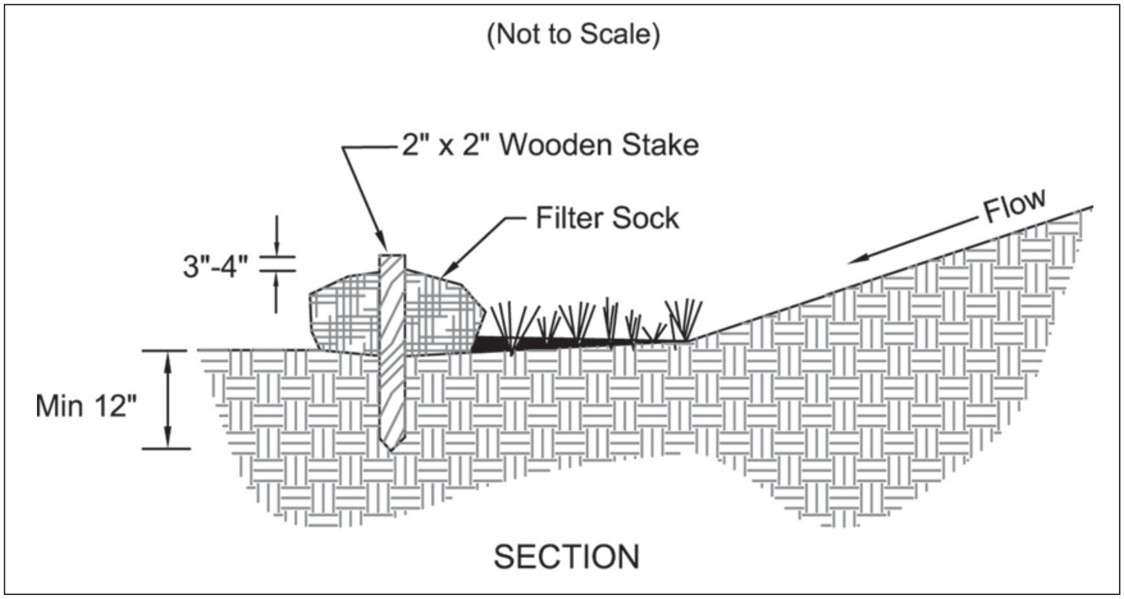
Maintenance – Filter socks should be regularly inspected to make sure they hold their shape, are ponding, and allowing adequate flow through. If ponding becomes excessive, filter socks should be replaced. Used filter socks may be cut and the compost dispersed and seeded to prevent captured sediment from being resuspended.

Removal – When construction is completed on site, the filter socks may be cut and dispersed with a loader, rake, bulldozer or other device to be incorporated into the soil or left on top of the soil for final seeding. The mesh netting material will be disposed of in normal trash container or removed by the contractor.

References

Standard Specification for Compost for Erosion/Sediment Control (Filter Berms) AASHTO Designation: MP-9 http://www.iaasla.org/NEWS/FILES/AASHTO-Filterberm6.doc

Specifications
for
Filter Sock



1. Materials – Compost used for filter socks shall be weed, pathogen and insect free and free of any refuse, contaminants or other materials toxic to plant growth. They shall be derived from a well-decomposed source of organic matter and consist of a particles ranging from 3/8" to 2".
2. Filter Socks shall be 3 or 5 mil continuous, tubular, HDPE 3/8" knitted mesh netting material, filled with compost passing the above specifications for compost products.

INSTALLATION:

3. Filter socks will be placed on a level line across slopes, generally parallel to the base of the slope or other affected area. On slopes approaching 2:1, additional socks shall be provided at the top and as needed mid-slope.
4. Filter socks intended to be left as a permanent filter or part of the natural landscape, shall be seeded at the time of installation for establishment of permanent vegetation.
5. Filter Socks are not to be used in concentrated flow situations or in runoff channels.

MAINTENANCE:

6. Routinely inspect filter socks after each significant rain, maintaining filter socks in a functional condition at all times.
7. Remove sediments collected at the base of the filter socks when they reach 1/3 of the exposed height of the practice.
8. Where the filter sock deteriorates or fails, it will be repaired or replaced with a more effective alternative.
9. Removal – Filter socks will be dispersed on site when no longer required in such as way as to facilitate and not obstruct seedings.

CHAPTER 7

Soil Stabilization

Soil Stabilization is the most effective means to minimize erosion and off-site sediment from development sites. Stabilized soils have vegetative or other types of cover left during construction or replaced following disturbance in order to prevent wind or water. Maintaining stabilization involves taking key steps at planning and continuing until the end of construction.

During project planning all efforts should especially be made to retain existing vegetation. This can be accomplished by phasing construction activity, using 'open space' design concepts, and minimizing corridor widths for road and utility construction. Special emphasis on preserving natural vegetation should be made near sensitive areas such as wetlands, stream corridors, steep slopes, and woodlots. Ideally, natural areas should be set aside permanently; however even delaying disturbance of portions of a site through phasing will prevent significant erosion from occurring. Areas not to be disturbed must be shown on construction plans and clearly marked in the field.

Once clearing and grading begins, erosion will occur until the site is re-stabilized. This occurs as rough or finish grading operations become idle or finished and are seeded and mulched as soon as possible, during any season. The most common methods, seeding and mulching are relatively inexpensive, easy to implement, and requires minimum maintenance. No matter which method is used, all stabilization practices significantly reduce off-site pollution and reliance on more costly and less reliable sediment treatment practices.

7.1 Minimized Phased Disturbance

Description

Phased disturbance limits the total amount of grading at any one time and sequences operations so that at least half the site is either left as undisturbed vegetation or re-stabilized prior to additional grading operations. This approach actively monitors and manages exposed areas, so that erosion is minimized and sediment controls can be more effective in protecting aquatic resources and downstream landowners.

Condition Where Practice Applies

This practice can be applied anywhere development occurs and is well suited to protect critical areas on and off site, such as wetlands, streams, ponds and highly erodible areas subject to high erosion rates. The practice is applicable where natural vegetation can act as a soil stabilizer during development and perhaps as a water quality feature after construction.

Planning Considerations

Two planning principles should be applied for phased disturbance. First, developments should be fit around the natural site conditions (e.g. topography, drainage, vegetation and setting) and thus involve less grading and fewer offsite impacts than conventional development patterns. Practically this means retaining undisturbed green space around water resources and on critical areas like steep slopes.

The second planning principle is focused on managing active construction, so that at least 50% of the land area is maintained in vegetation. By anticipating the timing and extent each grading and construction operation, along with erosion and sediment controls, exposed ground does not sit idle. This management principle is applied by developing phases of a project that can be brought to completion quicker than the entire parcel; and by utilizing an effective construction sequence to assist project managers to anticipate the next step towards stabilization and completion.

Ideally with phasing and effective sequencing, a parcel is divided between vegetated inactive areas and active areas where work is continuous from clearing operations, through grading, drainage and construction until final re-stabilization with vegetation. A realistic construction sequence is an essential planning tool for this practice with the goal that only areas under active construction have exposed soils.

Construction Operation	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
PHASE 1: Roadway, Storm & Utilities	←	—	—	—	—	—	→												
Install construction site entrance	•																		
Fence natural & tree protection area	•																		
Install SW/sed basin, diversion and silt F.		•																	
Seed SW/Sed basin areas		•																	
Clear ROW		•																	
Grading, install storm, San. and utilties		•	•																
Place inlet protection on storm sewers			•																
Grade road swales and stabilize			•	•															
Road construction				•	•														
Seed/mulch graded areas					•	•													
PHASE 1: Home Construction					←	—	—	—	—	→									
Clear home sites					•	•	•												
Install silt fence & filter berms					•														
Basement excavation & rough grading					•	•	•	•											
Temporary seeding on lots						•	•	•	•										
Final yard grading								•	•	•									
Permanent seed and mulch								•	•	•									
PHASE 2: Roadway, Storm & Utilities								←	—	—	→								
Install sediment trap, silt F. and filter B.								•											
Seed sediment trap								•											
Grading, install storm, San. and utilties									•	•									
Place inlet protection on storm inlets										•									
Erosion control matting on swales										•									
Road construction											•								
Winterization- Seed/mulch graded areas										•	•								
PHASE 2: Home Construction												←	—	—	—	—	—	—	→
Clear home sites												•	•						
Install filter berms													•						
Basement excavation														•	•				
Temporary seeding on lots															•	•	•		
Final yard grading																	•	•	
Permanent seeding and mulching																		•	•
Remove temp riser, clean out SW pond																			•
Adapt SW pond outlet for permanent configuration																			•

Figure 7.1.1 Sample Sequence of Construction Operations

Design Criteria

Specify all major construction operations including erosion and sediment controls with the estimated time for completion in a sequence of operations (see Figure 7.1.1). The sequence of operations shall be noted on construction drawings. Changes should be made to the construction sequence as work is completed or delayed.

Divide site work into major phases so that no more than 50% of the site is exposed at any one time. Within each phase, operations such as clearing can also be divided to keep from removing all the vegetation at once. For example, clearing for a roadway and infrastructure can be effectively separated from clearing operations required for homebuilding rather than removing all vegetation at once.

All areas that are disturbed shall be provided with appropriate controls such as sediment basins, traps or barriers to prevent sediment from impacting water resources or offsite areas. Disturbed areas that are expected to be inactive (idle) for 21 days or longer will be temporarily stabilized until the subsequent construction operations begin or permanent seeding and mulching can be completed.

Maintenance

Monitoring is essential to ensure that phasing and sequencing occur properly. This includes making sure only the areas that need to be exposed are exposed, and all other BMP practices are in good working order.

Routinely verify that work is progressing in accordance with the project's construction sequence. If progress deviates, take corrective actions.

When changes to the project schedule are unavoidable, amend the construction sequence schedule on drawings and plans well in advance to anticipate potential problems and maintain control.

Common Problems/Concerns

Proper planning not conducted – more than 50% of the site is bare at any one time. Areas may be too large and may need to be managed in smaller increments.

Active disturbance of the entire site does not allow portions to reach stages of completion so that temporary or permanent seeding and mulching can be employed. A failure to limit work areas to phases will result in erosion and sediment control being less effective.

Failure to anticipate completion dates for final or temporary grading stages can leave disturbed areas unprotected during winter months.

Failure to follow the construction sequence or maintain may result in erosion and sediment control items being delayed.

Temporary seeding and revegetation of graded areas is delayed as other work slows. Some areas such as slopes should proceed with seedings even though delays in other operations are occurring.

7.2 Clearing and Grubbing

Description

Clearing and grubbing is the removal of trees, brush and other unwanted material in order to develop land for other uses or provide access for site work. Clearing generally describes the cutting and removal of above ground material while grubbing is the removal of roots, stumps, and other unwanted material below existing grade.

Clearing and grubbing includes the proper disposal of materials and the implementation of best management practices in order to minimize exposure of soil to erosion and causing downstream sedimentation.

Condition Where Practice Applies

This practice may be applied anywhere existing trees and other material must be removed for development to occur.   The potential for erosion and sedimentation increases as: the vegetation removed; area disturbed or watercourses encountered increases.

Planning Considerations

Site assessment, selection and marking

Sites should be assessed to determine areas to be left undisturbed as well as trees or vegetated areas to be saved (see tree preservation area). These areas need to be clearly marked on plans and in the field. Land clearing activities should not begin until the site assessment and the field marking is concluded.

Timing and Phasing

Large-scale sites should be cleared in phases, with initiation of each phase delayed until actual construction is scheduled for that area of the site.

Erosion, sediment and stream instability potential

Clearing in some areas should be avoided or delayed due to the potential for destabilization. Cleared sites on heavy soils and steep slopes are subject to excessive erosion and may require additional practices to keep the soil in place. Land clearing during dry or frozen times will decrease compaction and potential water quality problems from runoff.

Stream corridors should be left in tact unless and until plans have been made to immediately restore stable conditions. These areas are subject to rapid erosion once vegetation is removed and soon become a source of sediment downstream. Alternatively naturally vegetated stream corridors help protect water resources from pollution generated during grubbing and grading operations.

Design Criteria

Timber Salvage – Develop plans specifying the kind and location of timber to be salvaged, the location of haul roads and skid trails, location and width of natural buffer zones around water bodies, and the location and methods of stream crossings. The method of disposing of all material that will not be salvaged should also be specified. Plans should also include the best management practices that will be used to protect the cleared area from erosion.

Identify and protect healthy trees following specifications in the **Tree and Natural Area Preservation** practice. Where possible, preserve a natural buffer/filter strip adjacent to all water bodies. Avoid clearing to the water bodies' edge.

1. Where it is necessary to clear to the water's edge, appropriate sediment control should be used and seeding and other stabilization should be initiated within 2 days of work becoming idle.
2. Phase work so that only part of the site is being cleared at any given time. This will reduce the amount of time soil is exposed to erosive forces. Follow examples in the **Phased Disturbance** practice.
3. Install earth diversions to intercept and divert runoff to stable outlets and appropriate sediment ponds.
4. All debris should be kept out of surface water resources. If possible, leave mulch or vegetation on the ground to decrease runoff and potential runoff. See the "Disposal Options" section, below.
5. Exposed areas not planning for immediate earthwork should be temporarily seeded to prevent further erosion at the site. See the **Temporary Seeding** practice. Additional stabilization or sediment control practices may be necessary to keep soil on the site.

Grubbing – Grubbing removes roots and stumps by digging or pushing over with earth moving equipment. Grubbing should be carefully monitored near lakes and streams to protect the water's edge. Removing root systems near the banks of streams and lakes make cause the area to become unstable and erode. If possible, avoid grubbing at all near the water's edge.

Tree Removal –

1. Where trees and stumps are removed in separate operations, trees may be used for commercial purposes such as lumber, firewood, or mulch.

2. Trees and stumps may be removed in one operation. This method leaves materials that can be useful in stream restoration and stabilization (e.g rootwads, vanes). may be used as a rootwads for streambank restoration work. Be certain that sufficient trunk is left for effective anchoring in the bank. Tops of trees should be removed and chipped for mulch.
3. Operating heavy equipment too close to trees will result in damage or loss due to soil disruption, compaction and trunk damage. It is recommended that all heavy equipment operations be limited to outside the drip line of all trees to be preserved. The drip line is the area from the trunk of the tree outward to a point at which there is no longer any overhanging vegetation.
4. In forested wetlands, shallow–rooted species are protected by each other from potential wind damage. Whenever trees are removed from a forested wetland, the possibility of blow downs or windthrow increases. Shallow rooted species are also protected by edge trees, which shield the prevailing wind side of the woodlot. It is helpful to leave as many edge trees as possible on the prevailing wind side of the cleared area.

Disposal Options –

Where possible, all stumps, roots, logs, brush, limbs, tops and other debris resulting from the clearing or thinning operation should be disposed of by processing through a chipping machine. The chips can then be utilized as mulch (see Mulching practice), as part of a site stabilization or final landscaping plan. Organic material may also be disposed of at an approved composting facility.

Note that treetops, stumps and field stone which are cleared and piled/windrowed in suitable areas can improve habitat for wildlife such as rabbits, raccoons, snakes, salamanders, toads and frogs.

Maintenance

Land clearing itself requires no maintenance except maintenance of the equipment used in the land clearing operation. Tree protection that utilizes fencing and signage should be maintained throughout the clearing stages. It is also important to maintain all other temporary and permanent practices that are used in conjunction with the land clearing to prevent soil erosion and sedimentation.

Common Problems / Concerns

Clearing of areas planned for preservation may occur and desirable species may be damaged, therefore preservation areas should be well marked.

During construction, naturally vegetated banks of stream and lakes may become destabilized. Clearly mark areas where natural vegetation must be maintained, and immediately implement stabilization plans of denuded areas.

As large areas are disturbed, site erosion potential drastically increases until cover is reestablished. Establish temporary seedings as soon as clearing/grubbing and grading activities stop or become idle.

7.3 Tree and Natural Area Reservation

Description

Tree and natural area preservation insures that important vegetated areas existing on-site prior to development will survive the construction process. Tree protection areas prevent the losses and damages to trees that are common as a result of construction. This practice is useful to protect individual trees, and areas of forest or natural vegetation in stream corridors, or open space.

Conditions Where Practice Applies

This practice is applicable to any tree, forested or naturally vegetated area planned for long-term survival and subject to construction impacts. Existing trees provide valuable benefits during and after construction including: reduced erosion, reduced runoff rates and volume, reduced cooling costs, sound and visual barriers and higher property values.

Planning Considerations

Preservation of important natural areas must begin before the location of buildings, roads and utilities is determined. Early site planning should include delineating forested areas and significant trees and creating an inventory of the existing trees on-site. These should influence the placement of roads, buildings, and parking areas in the same manner as topography, streams and wetlands.

Tree Stand Delineation – Useful information for the delineation may include:

- Stands of trees to be preserved
- Individual trees of significance due to age, size, history, or aesthetic value

- Hazard trees to be removed
- Open areas
- Sensitive areas such as wetlands, riparian corridors, important wildlife habitat
- Other important natural or historic features.

***Tree Survey (Inventory)* –** A tree inventory or survey provides more detailed information about tree resources. Key to this step is outlining, on the engineering plans, the root zone of trees that may be impacted during construction. A method to calculate the root zone is to allow one-foot of radius for each inch of trunk diameter at breast height. Alternatively drip line or outline of the furthest hanging branches can be used (see the figure). Information to include in the tree survey includes:

- All trees to be impacted by proposed construction and critical root zone
- Diameter of tree
- Species of tree
- Health of tree
- Notes on crown or root condition

Note regarding tree survival: A tree's root zone is critical to its ability to survive. Damaging the root zone during construction will lead to the tree's decline and ultimately its death within 1 to 10 years. Ninety-five percent of a tree's roots are in the upper 12-18 inches of soil, and the majority of the roots supplying nutrients are found just below the soil surface. The critical root zone extends at least to the drip zone of a tree and must be protected from soil compaction, grubbing, filling activities, and other disturbances.

Design Criteria

***Site Plan* -** With the tree survey data and high value natural areas clearly shown on a base map, site designers can plan the location of roads, utilities, and other improvements to minimize impacts. Regarding trees, the plan identifies tree preservation areas as well as those trees that will be severely impacted by development, and which may need to be removed.

The following should be shown on the erosion and sediment control plans and clearly marked on site:

- Limits of clearing and grubbing
- Natural preservation areas including the specimens (detail extent and type)
- Construction roads and stockpile areas outside of preservation areas
- Notes and drawings detailing measures to protect preservation areas during construction,
- Notes and drawings detailing protect preservation areas following construction,
- Areas for planting.

***Protection During Construction for Tree Preservation Areas* -** Construction administration is the on-site protection and care of trees selected to remain. The following are necessary activities for adequate protection:

- **Prevent any filling, compaction, storage, or excavation within the tree protection zone.** Weight and traffic on a tree's root zone cause soil compaction. This reduces air and water movement to the tree's root system and is a major cause of tree decline.

- **Fence out construction traffic.** Tree protection areas must be made visible during construction. A physical barrier of a fence and signage must be in place prior to clearing and remain in place throughout construction.
- **Delineate parking, material storage, and cement washout areas to prevent inappropriate areas from being utilized.**
- **Supervise clearing activities to insure "save" areas are preserved.**

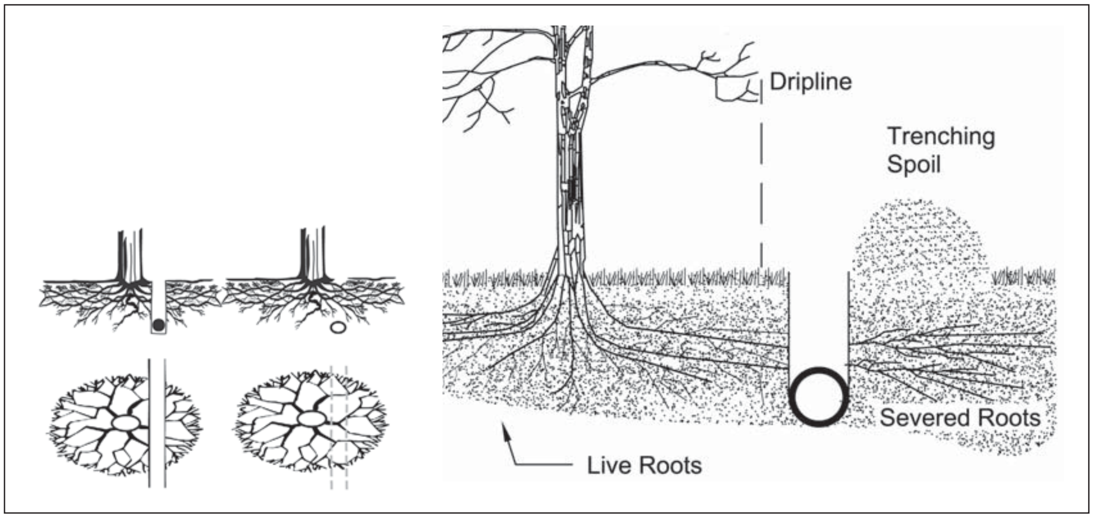


Figure 7.3.1 Inappropriate trenching (40% root loss) versus Tunneling (no significant root loss) and more appropriate trenching.

- **Supervise trenching, excavation and tunneling near trees to be saved.** Trenching near trees effectively cuts off large portions of a tree's root system (see figure). Ideally trenching should stay beyond the drip zone of a tree. A better alternative is to tunnel beneath the root zone at a depth greater than 2 feet.
- **Care for damaged trees.** Cutting damaged root systems clean and removing damaged branches may aid slightly damaged trees.

Provide a permanent visual barrier - Protecting forest vegetation permanently requires visual barriers to encroachment. It is not enough to protect areas with conservation easements, deed restrictions or even separate ownership. Forested stream buffers, parks and valuable wood lots are often severely degraded by mowing, removal of the understory and ground cover plants, and dumping of yard waste. Permanent signs or fences should identify the area and describe allowable uses.

Common Concerns

The following consequences can result from tree damage during construction activities:

- Loss of individual or groups of trees
- Long term decline of tree health
- Increased personal property damage
- Reduced property values
- Increased cost of removal once the project is complete

References:

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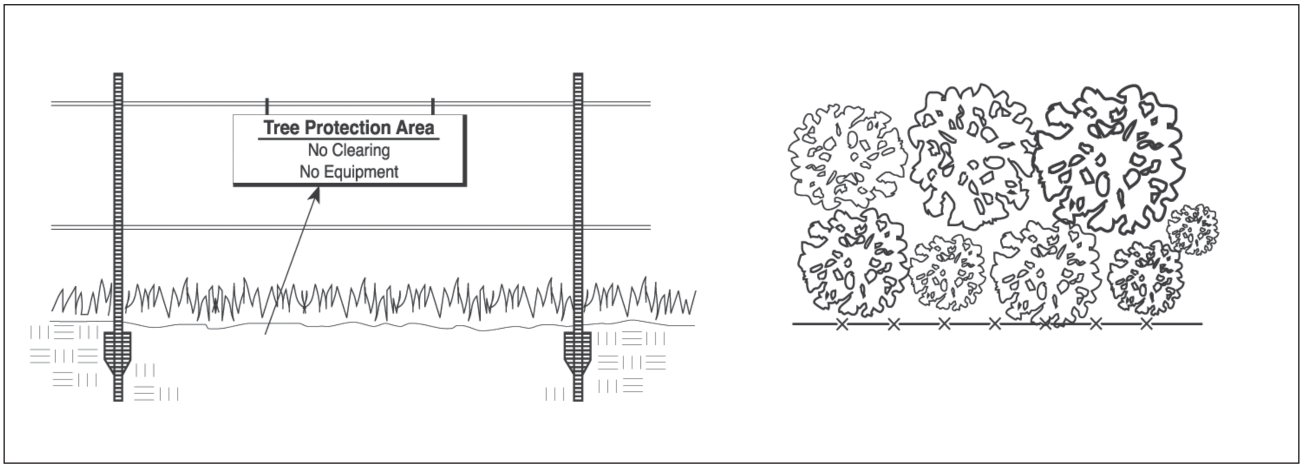
Specifications
for

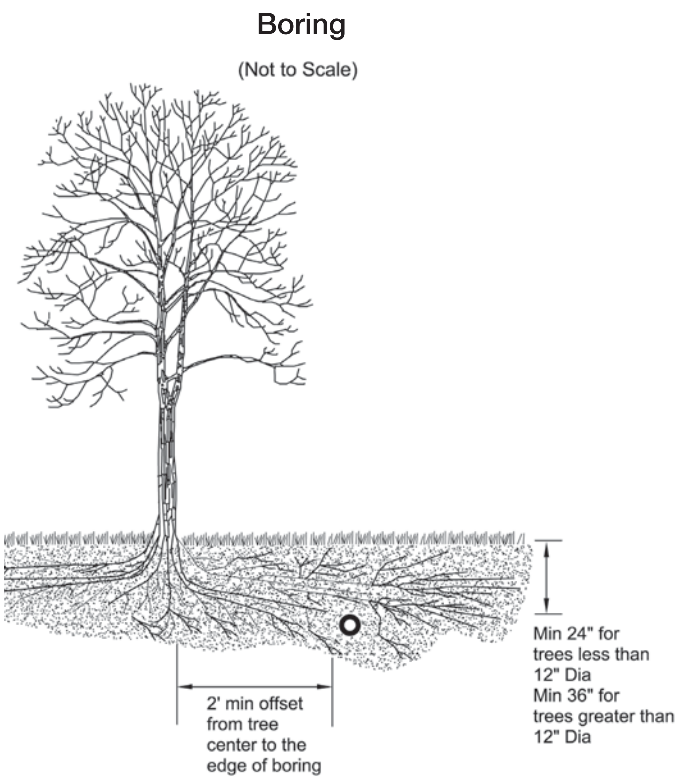
Tree and Natural Area Preservation

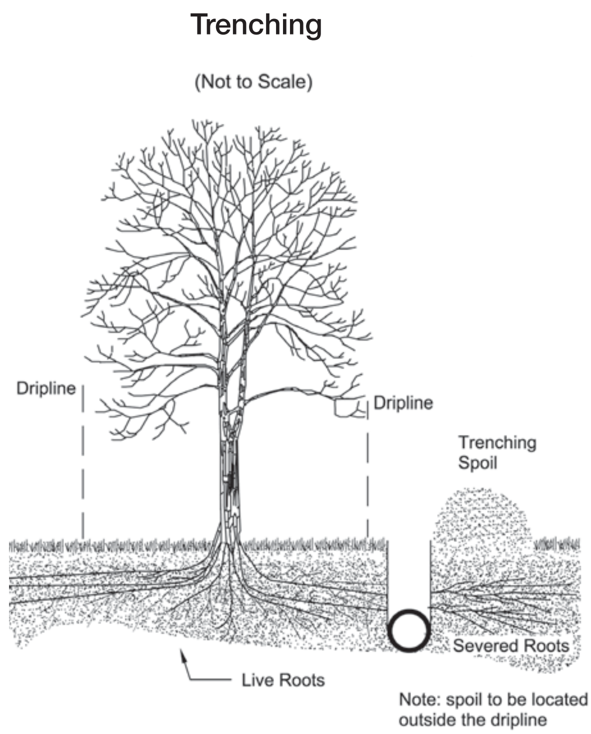


1. Tree and natural area preservation shall be fenced prior to beginning clearing operations.
2. Fence materials shall be metal fence posts with two strands of high tensile wire, plastic fence or snow fence.
3. Signage shall clearly identify the tree and natural preservation area and state that no clearing or equipment is allowed within it.
4. Fence shall be placed as shown on plans and beyond the drip line or canopy of trees to be protected.
5. If any clearing is done around specimen trees it shall be done by cutting at ground level with hand held tools and shall not be grubbed or pulled out. No clearing shall be done in buffer strips or other preserved forested areas.
6. No filling or stockpiling of materials shall occur within the tree protection area, including deposition of sediment.

Specifications
for

Protection During Utility Installation





1. Where utilities must run through a tree's dripline are, tunneling should be used to minimize root damage. Tunneling should be performed at a minimum depth of 24 inches for trees less than 12 inches in diameter or at a minimum depth of 36 inches for larger diameter trees.
2. Where tunneling will be performed within the dripline of a tree, the tunnel should be placed a minimum of 2 feet away from the tree trunk to avoid taproots.
3. Minimize excavation or trenching within the dripline of the tree. Route trenches around the dripline of trees.
4. Roots two inches or larger that are severed by trenching should be sawn off neatly in order to encourage new growth and discourage decay.
5. Soil excavated during trenching shall be piled on the side away from the tree.
6. Roots shall be kept moist while trenches are open and refilled immediately after utilities are installed or repaired

7.4 Construction Entrance

Description

A construction entrance is a stabilized pad of stone underlain with a geotextile and is used to reduce the amount of mud tracked off-site with construction traffic. Located at points of ingress/egress, the practice is used to reduce the amount of mud tracked off-site with construction traffic.

Conditions Where Practice Applies

A construction entrance is applicable where:

- Construction traffic leaves active construction areas and enters public roadways or areas unchecked by effective sediment controls;
- Areas where frequent vehicle and equipment access is expected and likely to contribute sediment to runoff, such as at the entrance to individual building lots.

Planning Considerations

Construction entrances address areas that contribute significant amounts of mud to runoff by providing a stable area for traffic. Although they allow some mud to be removed from construction vehicle tires before they enter a public roads, they should not be the only practice relied upon to manage off-site tracking. Since most mud is flung from tires as they reach higher speeds, restricting traffic to stabilized construction roads, entrances and away from muddy areas is necessary.

If a construction entrance is not sufficient to remove the majority of mud from wheels or there is an especially sensitive traffic situation on adjacent roads, wheel wash areas may be necessary. This requires an extended width pad to avoid conflicts with traffic, a supply of wash water and sufficient drainage to assure runoff is captured in a sediment pond or trap.

Proper installation of a construction entrance requires a geotextile and proper drainage to insure construction site runoff does not leave the site. The use of geotextile under the stone helps to prevent potholes from developing and will save the amount of stone needed during the life of the practice. Proper drainage may include culverts to direct water under the road-way or water bars to direct muddy water off the roadway toward sediment traps or ponds.

Design Criteria

The area of the entrance must be cleared of all vegetation, roots, and other objectionable material. Geotextile will then be placed the full width and length of the entrance.

Stone shall be placed to a depth of at least 6 inches. Roads subject to heavy duty loads should be increased to a minimum of 10 inches. Surface water shall be conveyed under the entrance, through culverts, or diverted via a water bars or mountable berms (minimum 5:1 slopes) so as to convey sediment laden runoff to sediment control practices or to allow clean water to pass by the entrance.

The stabilized construction entrance shall meet the specifications that follow.

Maintenance

The entrance shall be maintained in a condition that will prevent tracking or flow of mud onto public rights-of-way. This may require periodic top dressing with additional stone or the washing and reworking of existing stone as conditions demand and repair and/or cleanout of any structures used to trap sediment. All materials spilled, dropped, washed, or tracked from vehicles onto roadways or into storm drains must be removed immediately. The use of water trucks to remove materials dropped, washed, or tracked onto roadways will not be permitted under any circumstances.

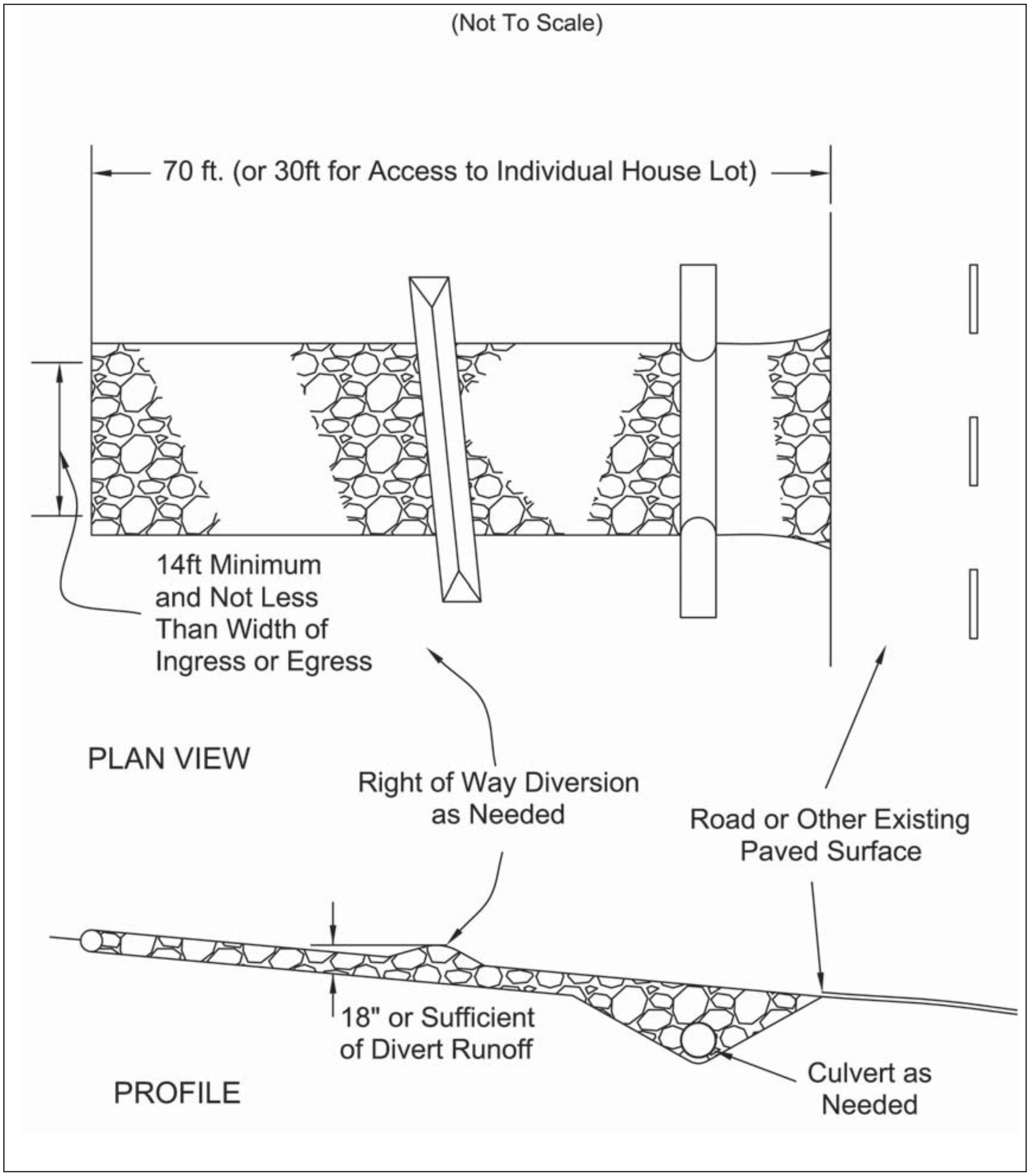
Common Problems / Concerns

Mud is allowed to accumulate and is tracked on to public right-of-ways. The entrance and associated construction roads may need dressing with additional stone.

Soft depression areas develop in entrance area. Stone may not have been underlain with geotextile or insufficient stone base has been provided.

Specifications
for

Construction Entrance



Specifications
for

Construction Entrance

1. Stone Size—ODOT # 2 (1.5-2.5 inch) stone shall be used, or recycled concrete equivalent.
2. Length—The Construction entrance shall be as long as required to stabilize high traffic areas but not less than 70 ft. (exception: apply 30 ft. minimum to single residence lots).
3. Thickness -The stone layer shall be at least 6 inches thick for light duty entrances or at least 10 inches for heavy duty use.
4. Width -The entrance shall be at least 14 feet wide, but not less than the full width at points where ingress or egress occurs.
5. Geotextile -A geotextile shall be laid over the entire area prior to placing stone. It shall be composed of strong rot-proof polymeric fibers and meet the following specifications:

Figure 7.4.1

Geotextile Specification for Construction Entrance	
Minimum Tensile Strength	200 lbs.
Minimum Puncture Strength	80 psi.
Minimum Tear Strength	50 lbs.
Minimum Burst Strength	320 psi.
Minimum Elongation	20%
Equivalent Opening Size	EOS < 0.6 mm.
Permittivity	1×10-3 cm/sec.

6. Timing—The construction entrance shall be installed as soon as is practicable before major grading activities.
7. Culvert -A pipe or culvert shall be constructed under the entrance if needed to prevent surface water from flowing across the entrance or to prevent runoff from being directed out onto paved surfaces.
8. Water Bar -A water bar shall be constructed as part of the construction entrance if needed to prevent surface runoff from flowing the length of the construction entrance and out onto paved surfaces.
9. Maintenance -Top dressing of additional stone shall be applied as conditions demand. Mud spilled, dropped, washed or tracked onto public roads, or any surface where runoff is not checked by sediment controls, shall be removed immediately. Removal shall be accomplished by scraping or sweeping.
10. Construction entrances shall not be relied upon to remove mud from vehicles and prevent off-site tracking. Vehicles that enter and leave the construction-site shall be restricted from muddy areas.
11. Removal—the entrance shall remain in place until the disturbed area is stabilized or replaced with a permanent roadway or entrance.

7.5 Dust Control

Description

Dust control involves preventing or reducing dust from exposed soils or other sources during land disturbing, demolition and construction activities to reduce the presence of airborne substances which may present health hazards, traffic safety problems or harm animal or plant life.

Conditions Where Practice Applies

In areas subject to surface and air movement of dust where on-site and off-site damage is likely to occur if preventive measures are not taken.

Planning Considerations

Construction activities inevitably result in the exposure and disturbance of soil. Fugitive dust results from both construction activities and as a result of wind erosion over the exposed earth surfaces. Large quantities of dust are typically generated in heavy construction activities, such as road construction and subdivision, commercial or industrial development, which involve disturbing significant areas of the soil surface. Research of construction sites has established an average dust emission rate of 1.2 tons/acre/month for active construction. Earth-moving activities comprise the major source of construction dust emissions, but traffic and general disturbance of the soil also generate significant dust emissions.

Planning for dust control involves limiting the amount of soil disturbance at any one time as a key objective. Therefore, phased clearing and grading operations (minimize disturbance-phasing) and the utilization of other stabilization practices can significantly reduce dust emissions. Undisturbed vegetative buffers (minimum 50-foot widths) left between graded areas and protected areas can also be very helpful in dust control by providing windbreaks and non-erosive areas.

Design Criteria

A number of measures can be utilized to limit dust either during or between construction stages or once construction is complete. Generally the same methods that are used to limit erosion by limiting exposure of soils to rainfall can be used to limit dust including: stabilizing exposed soils with mulch, vegetation or permanent cover. Additional methods particular to dust control include managing vehicles and construction traffic, road treatment and treatment of exposed soil with chemical stabilizers.

Vegetative Cover – The most effective way to prevent dust from exposed soil is to provide a dense cover of vegetation. In areas subject to little or no construction traffic, vegetative stabilization reduces dust drastically. Timely temporary and permanent seedings must be utilized to accomplish this. See TEMPORARY SEEDING & PERMANENT SEEDING.

Mulch - When properly applied, mulch offers a fast, effective means of controlling dust. Mulching is not recommended for areas within heavy traffic pathways. Binders or tackifiers should be used to tack organic mulches. See MULCHING.

Rough Graded Soils – Leaving the soil in a temporary state of rough grade, where clods rather than flattened soils predominate the surface can reduce the amount of dust generated from areas during periods of higher winds. This must be balanced by the need to reach a stage where the soil can be stabilized and may be only be necessary when high winds are predicted.

Watering - This is the most commonly used dust control practice. The site is sprinkled with water until the surface is wet before and during grading and is repeated as needed. It offers fast protection for haul roads and other heavy traffic routes. Watering should be done at a rate that prevents dust but does not cause soil erosion. Wetting agents are also available to increase the effectiveness of watering and must follow manufacturers instructions.

Chemical Stabilizers/Wetting Agents – Many products of this type are available and are usually most effective on typical mineral soils but may not be on predominantly organic soils such as muck. Users are advised to pay attention to the limitations and instructions regarding each product. The following table lists various adhesives and provides corresponding information on mixing and application:

Table 7.5.1 Adhesives for Dust Control

Adhesive	Water Dilution (Adhesive: Water)	Nozzle Type	Application Rate Gallon/Acre
Latex Emulsion	12.5:1	Fine	235
Resin in Water	4:1	Fine	300
Acrylic Emulsion (No-traffic)	7:1	Coarse	450
Acrylic Emulsion (Traffic)	3.5:1	Coarse	350

Stone - Stone can be used to stabilize roads or other areas during construction using crushed stone or coarse gravel. Research has shown the addition of bentonite to limestone roads (not igneous gravel) has shown benefits in reducing dust.

Windbreaks and Barriers – Where dust is a known problem, existing windbreak vegetation should be preserved. Maintaining existing rows of trees or constructing a wind fence, sediment fence, or similar barrier can help to control air currents and blowing soil. Place barriers perpendicular to prevailing air currents at intervals of about 15 times the barrier height.

Calcium Chloride - This chemical may be applied by mechanical spreader as loose, dry granules or flakes at a rate that keeps the surface moist but not so high as to cause water pollution or plant damage. Liquid application of a 35% calcium chloride solution is common. Note: application rates should be strictly in accordance with suppliers' specified rates.

Street Cleaning - Paved areas that have accumulated sediment from construction sites should be cleaned daily, or as needed, utilizing a street sweeper or bucket -type loader or scraper.

Operation and Maintenance

Most dust control measures, such as applications of water or road treatments will require monitoring and repeat applications as needed to accomplish good control.

Common Problems / Concerns

Vegetation is removed from large areas of the construction site and left barren for long periods of time.

Continuous, scheduled monitoring of the construction site conditions is not made.

Specifications
for

Dust Control

1. Vegetative Cover and/mulch – Apply temporary or permanent seeding and mulch to areas that will remain idle for over 21 days. Saving existing trees and large shrubs will also reduce soil and air movement across disturbed areas. See Temporary Seeding; Permanent Seeding; Mulching Practices; and Tree and Natural Area Protection practices.
2. Watering – Spray site with water until the surface is wet before and during grading and repeat as needed, especially on haul roads and other heavy traffic routes. Watering shall be done at a rate that prevents dust but does not cause soil erosion. Wetting agents shall be utilized according to manufacturers instructions.
3. Spray-On Adhesives – Apply adhesive according to the following table or manufacturers' instructions.

Table 7.5.1 Adhesives for Dust Control

Adhesive	Water Dilution (Adhesive: Water)	Nozzle Type	Application Rate Gal./Ac.
Latex Emulsion	12.5:1	Fine	235
Resin in Water Acrylic Emulsion (No-traffic)	4:1	Fine	300
Acrylic Emulsion (No-traffic)	7:1	Coarse	450
Acrylic Emulsion (Traffic)	3.5:1	Coarse	350

4. Stone – Graded roadways and other suitable areas will be stabilized using crushed stone or coarse gravel as soon as practicable after reaching an interim or final grade. Crushed stone or coarse gravel can be used as a permanent cover to provide control of soil emissions.
5. Barriers – Existing windbreak vegetation shall be marked and preserved. Snow fencing or other suitable barrier may be placed perpendicular to prevailing air currents at intervals of about 15 times the barrier height to control air currents and blowing soil.
6. Calcium Chloride - This chemical may be applied by mechanical spreader as loose, dry granules or flakes at a rate that keeps the surface moist but not so high as to cause water pollution or plant damage. Application rates should be strictly in accordance with suppliers' specified rates.
7. Operation and Maintenance - When Temporary Dust Control measures are used; repetitive treatment should be applied as needed to accomplish control.

   Street Cleaning - Paved areas that have accumulated sediment from construction should be cleaned daily, or as needed, utilizing a street sweeper or bucket -type endloader or scraper.

7.6 Grade Treatment (Surface Roughening)

Description

Grade Treatment or surface roughening creates horizontal depressions in the soil surface that help to reduce erosion by reducing runoff velocity and increasing infiltration. These depressions aid in the establishment of vegetative cover and provide localized trapping of sediments. Grade Treatment is typically created by operating tillage implements on the contour or by running tracked equipment up and down a slope without fine grading the surface.

Conditions Where Practice Applies

1. All slopes steeper than 3:1 require grade treatment, either stair-step grading, grooving, furrowing, or tracking if they are to be stabilized with vegetation.
2. Areas with grades less steep than 3:1 should have the soil surface lightly roughened and loose to a depth of 2 to 4 inches prior to seeding.
3. Areas that have been graded and will not be seeded immediately may be roughened to reduce runoff velocity until seeding takes place.
4. Slopes with a stable rock face do not require roughening or stabilization.

Planning Considerations

A grading plan should be developed to establish drainage areas, direct drainage patterns, and decrease runoff velocities. The plan should coordinate the grading with the erosion/ sedimentation control plan and the stormwater management plan. Grading should be done in stages according to the implementation schedule, thus limiting the amount of surface area left in a disturbed, unstable condition. When grading, leave a natural buffer between the disturbed areas and the water body (50 ft. minimum width recommended.) If a natural buffer cannot be left, construct a berm or install other appropriate sediment control BMPs (i.e. sediment trap, silt fence) adjacent to the water body.

Prior to placing fill, topsoil and organic materials should be removed. To prevent differential settlement, fill should be free of objectionable materials such as logs, rocks and stumps. Frozen fill or organic (muck) materials should not be used.

Spoil and topsoil piles shall not be located in or near drainageways and shall be stabilized as soon as possible by seeding and mulching. Placing piles adjacent to channel banks where it may create bank failure or result in deposition of sediment downstream should be avoided.

Graded areas with smooth, hard surfaces give a false impression of "finished grading" and a job well done. It is difficult to establish vegetation on such surfaces due to reduced water infiltration and the potential for erosion. Rough slope surfaces with uneven soil and rocks left in place may appear unattractive or unfinished at first, but encourage water infiltration, speed the establishment of vegetation, and decrease runoff velocity.

Rough loose soil surfaces give lime, fertilizer and seed some natural coverage. Niches in the surface provide microclimates that generally provide a cooler and more favorable moisture level than hard flat surfaces; this aids seed germination.

Design Criteria

Grade Treatment is to be performed only after all cuts and fills are made and brought to the final shape and grade.

There are different methods for achieving a roughened soil surface on a slope, and the selection of an appropriate method depends upon the type of slope. Grading methods include stair-step grading, grooving, and tracking.

Stair-step grading. This method should be done on slopes steeper than 3:1 with material soft enough to be bulldozed and which will not be mowed. The vertical cut should be less than the horizontal distance and should not exceed 2 feet in soft material and 3 feet in rocky material. The horizontal position of the "step" should be sloped toward the vertical up-hill wall.

Grooving. This method can be done on any area, which can safely accommodate disks, tillers, spring harrow, or the teeth of a front-end loader bucket. In areas, which will not be mowed, use equipment to create grooves perpendicular to the slope. Grooves should not be less than 3 inches deep, nor more than 15 inches apart. In cuts, fills, and areas that will be mowed, grooves should be less than 10 inches apart and not less than 1 inch deep.

Tracking. This method is done by running tracked machinery (such as bulldozers) up and down slopes to leave horizontal depressions in the soil. Back-blading should not be done during the final grading operation.

Tracking or roughening with tracked machinery is not recommended on clayey soils unless other alternatives are unavailable due to its likelihood of causing compaction of the surface soil. Sandy soils do not compact severely, and may be tracked. In no case is tracking as effective as the other roughening methods described. To roughen with tracked machinery, operate the equipment up and down the slope to leave horizontal depressions in the soil with as few passes of the machinery as possible to minimize compaction.

Factors to be considered in choosing a method are slope steepness, mowing requirements, and whether the slope is formed by cutting or filling.

1. Disturbed areas, which will not require mowing, may be stair-step graded, tracked, grooved, or left rough after filling.
2. Stair-step grading is particularly appropriate in soils containing large amounts of soft rock. Each "step" catches material shed from above, and provides a level site where vegetation can become established.
3. Areas that will be mowed (these areas should have slopes 3:1 or flatter) may have small furrows left by discing, harrowing, raking, or seed-planting machinery operated on the contour.
4. Avoid excessive compacting of the soil surface when scarifying. Tracking with bulldozer treads is preferable to not roughening at all, but is not as effective as other forms of roughening, as the soil surface may be compacted and runoff increased.

Maintenance

Roughened areas shall be seeded and mulched within seven (7) days of last disturbance to obtain optimum seed germination and seedling growth.

Common Problems / Concerns

Severe compaction due to equipment operation – results in unsuitable seedbed and poor vegetation establishment.

Rough areas difficult to mow – caused by cutting grooves too deep or excessive erosion from grooves not being on the contour.

Grooving done perpendicular, rather than parallel to slope – results in accelerated erosion.

Specifications
for

Grade Treatment

Cut Slopes-Greater than 3:1 Slopes

1. Stair-step grading may be carried out on any material soft enough to be ripped with a bulldozer. The ratio of the horizontal distance to the vertical cut distance shall be flatter than 1:1 and the horizontal portion of the "step" shall slope toward the vertical wall. Individual vertical cuts shall not be more than 24 inches on soft soil materials and not more than 36 inches in rocky materials.
2. Grooving may be made with any appropriate implement which can be safely operated on the slope and which will not cause undue compaction. Suggested implements include discs, tillers, spring harrows, and the teeth on a front-end loader bucket. Such grooves shall not be less than 3 inches deep nor further than 15 inches apart.

Fill Slopes-Greater than 3:1 Slopes

Fill slopes steeper than 3:1 shall be grooved or allowed to remain rough as they are constructed utilizing method (1) or (2) below.

1. Grooving may be made with any appropriate implement which can be safely operated on the slope and which will not cause undue compaction such as discs, tillers, spring harrows, and the teeth on a front-end loader bucket. Grooves left shall not be less than 3 inches deep nor further than 15 inches apart.
2. As lifts of the fill are constructed, soil and rock materials may be allowed to fall naturally onto the slope surface. At no time shall slopes be bladed or scraped to produce a smooth, hard surface.

Cuts, Fills, and Graded Areas Which Will Be Mowed

1. Mowed slopes should not be steeper than 3:1 and shall avoid excessive roughness. These areas may be roughened with shallow grooves such as those, which remain after tilling, discing, harrowing, raking, or use of a cultipacker-seeder. The final pass of any such tillage implement shall be on the contour (perpendicular to the slope).
2. Grooves formed by implements shall be not less than 1 inch deep and not further than 12 inches apart. Fill slopes that are left rough during construction may be smoothed with a chain harrow or similar implement to facilitate mowing.

Roughening With Tracked Machinery

1. Avoid tracking clayey soils if possible, due to their potential for compaction. Conversely sandy soils will have low potential for compaction.
2. Operate tracked machinery up and down the slope to leave horizontal depressions in the soil. As few passes of the machinery should be made as possible to minimize compaction.

7.7 Topsoiling

Description

Topsoiling occurs during grading operations as the upper most organic layer of soil is stripped and stockpiled from areas being graded and subsequently replaced on the newly graded areas. Topsoil provides a more suitable growing medium than subsoil or on areas with poor moisture, low nutrient levels, undesirable pH, or in the presence of other materials that would inhibit establishment of vegetation. Replacing topsoil helps plant growth by improving the water holding capacity and nutrient content and consistency of the soils.

Conditions Where Practice Applies

This practice applies anywhere a good stand of vegetation is desired, whether turf, ornamental plants, and/ or vegetative cover especially in areas where high-quality turf is desirable to withstand intense use or meet aesthetic requirements, although it may not be appropriate for areas with slopes greater than 2:1.

This practice is especially applicable to areas where:

- existing soil structure, pH, or nutrient balance cannot be easily improved with soil amendments to be a suitable growth medium.
- existing soils are too shallow to provide adequate rooting depth or;
- the existing soil contains substances toxic to the desired vegetation.

Planning Considerations

Topsoil is the upper layer of natural soil (A horizon), which is typically darker and more fertile than the subsoil due to increased amounts of organic material. This layer is typically very evident as a person excavates through soil horizons. Project sites will have varying degrees of topsoil resources prior to construction, with some historically eroded sites having limited topsoil resources. These sites may have less justification for moving, stockpiling and re-spreading the top horizon of soil. If in question, assistance by a trained soils professional should be sought to determine the extent of topsoil resources on the project site.

Although replacing topsoil is critical to establishing good vegetation and limiting runoff from development sites, it comes with additional costs. Stripping, stockpiling and reapplying topsoil or importing topsoil will require greater work in grading operations and therefore will increase costs. Topsoiling will also add time to grading operations and may increase the exposure time of denuded areas. Additionally, depending on the original vegetative cover, topsoil often contains weed seeds that may compete with desirable species.

In site planning, the option of topsoiling should be compared with that of preparing a seedbed in subsoil. The clay content of subsoil does provide high moisture availability and deters leaching of nutrients. When adjusted for optimal pH and nutrient availability, subsoil may provide an adequate growth medium that is generally free of weeds. Topsoiling may not be required to establish less demanding, lower maintenance plants, although runoff will be increased due to the lack of topsoil from the site.

If topsoiling is planned, locations for topsoil stockpiles must be determined where drainage and site work will not be encumbered. Construction scheduling must be adjusted to allow sufficient time for moving, stockpiling and spreading topsoil between grading and re-vegetation operations.

Design Criteria

These are provided in the specifications that follow.

Maintenance

Topsoil stockpiles should be stabilized with temporary vegetation and provided sufficient sediment controls. Sediment Controls will need regular inspection and appropriate repairs as needed.

Common Problems / Concerns

- Care must be taken not to apply topsoil to subsoil if the two soils have contrasting textures. Clayey topsoil over sandy subsoil is a particularly poor combination, as water may creep along the junction between the soil layers, leading to sloughing of the topsoil. Sandy topsoil over clay subsoil is equally likely to fail.
- If topsoil and subsoil are not properly bonded, water will not infiltrate the soil profile evenly and it will be difficult to establish vegetation. Topsoiling of steep slopes is highly discouraged, unless good bonding of soils can be achieved.
- Topsoil should not be applied in excessively wet/moist conditions.

Specifications
for

Topsoiling

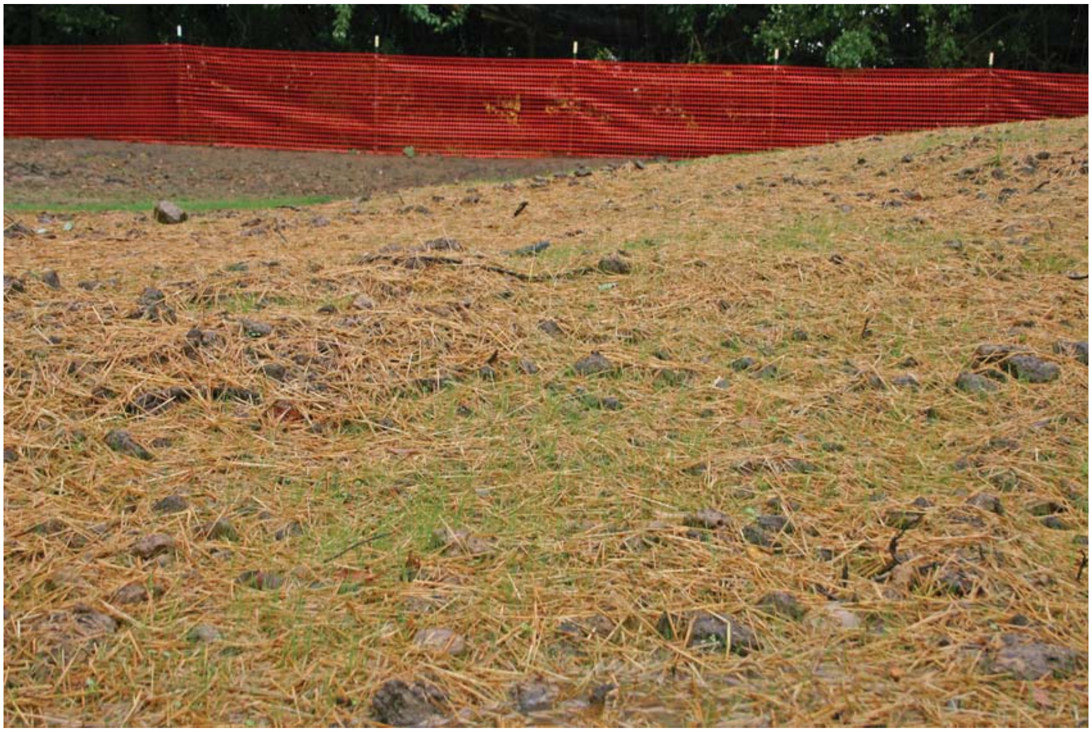
Salvaging and Stockpiling

1. Determine the depth and suitability of topsoil at the site. (For help, contact your local SWCD office to obtain a county soil survey report).
2. Prior to stripping topsoil, install appropriate downslope erosion and sedimentation controls such as sediment traps and basins.
3. Remove the soil material no deeper than what the county soil survey describes as "surface soil" (ie. A or Ap horizon).
4. Construct stockpiles in accessible locations that do not interfere with natural drainage. Install appropriate sediment controls to trap sediment such as silt fence immediately adjacent to the stockpile or sediment traps or basins downstream of the stockpile. Stockpile side slopes shall not exceed a ratio of 2:1.
5. If topsoil is stored for more than 21days, it should be temporary seeded, or covered with a tarp.

Spreading the Topsoil

1. Prior to applying topsoil, the topsoil should be pulverized.
2. To ensure bonding, grade the subsoil and roughen the top 3-4 in. by disking.
3. Do not apply when site is wet, muddy, or frozen, because it makes spreading difficult, causes compaction problems, and inhibits bonding with subsoil.
4. Apply topsoil evenly to a depth of at least 4 inches and compact slightly to improve contact with subsoil.
5. After speading, grade and stabilize with seeding or appropriate vegetation.

7.8 Temporary Seeding



Description

Temporary seedings establish temporary cover on disturbed areas by planting appropriate rapidly growing annual grasses or small grains. Temporary seeding provides erosion control on areas in between construction operations. Grasses, which are quick growing, are seeded and usually mulched to provide prompt, temporary soil stabilization. It effectively minimizes the area of a construction site prone to erosion and should be used everywhere the sequence of construction operations allows vegetation to be established.

Conditions Where the Practice Applies

Temporary seeding should be applied on exposed soil where additional work (grading, etc.) is not scheduled for more than 21 days. Permanent seeding should be applied if the areas will be idle for more than one year.

Planning Considerations

This practice has the potential to drastically reduce the amount of sediment eroded from a construction site. Erosion control efficiencies greater than 90% will be achieved with proper applications of temporary seeding. Because practices used to trap sediment are usually much less effective, temporary seeding is to be use even on areas where runoff is treated by sediment trapping practices. Because temporary seeding is highly effective and practical on construction sites, its liberal use is highly recommended.

Design Criteria

Specifications follow these explanations of important aspects of temporary seeding.

Plant Selection: Select the plants appropriate from the table in the Specifications for Temporary seeding. Choose varieties of tall fescue that are endophyte free or have non-toxic endophytes. Seeding rates for dormant seedings are increased by 50 percent. More information on dormant seedings is given in the permanent seeding section.

The length of time the area will idle and the season in which seeding occurs should influence the selection of seeding species. For areas remaining idle for over a year, a mixture containing perennial ryegrass is recommended. Cereal grains (rye, oats and wheat) are included in some of the mixtures as cover crops. These are annual plants that will die after producing seed. Realize that oats will not over-winter and continue to grow as wheat and rye do.

Site preparation: Temporary seeding is best done on a prepared soil seedbed of loose pulverized soil. However, seedings should not be delayed, if additional grading operations are not possible. At a minimum, remove large rock or debris that will interfere with seeding operations. If the ground has become crusted, a disk or a harrow should be used to loosen the soil. Overall the best soil conditions will exist immediately after grading operations cease, when soils remain loose and moist.

Soil amendments: A soil test is necessary to adequately predict the need for lime and fertilizer. Seedings that are expected to be long lasting (over 1-3 months), should have lime and fertilizer applied as recommended by a soil test. In lieu of a soil test, fertilizer can be broadcast and worked into the top inch of soil at the rate of 6 pounds/1000 ft2 or 250 pounds per acre of 10-10-10 or 12-12-12.

Seeding Methods: Seed shall be applied uniformly with a cyclone spreader, drill, culti-packer seeder, or hydroseeder. When feasible, seed that has been broadcast shall be covered by raking or dragging and then lightly tamped into place using a roller or cultipacker. If hydroseeding is used, the seed and fertilizer will be mixed on-site and the seeding shall be done immediately and without interruption.

Maintenance

Areas failing to establish vegetative cover adequate to prevent erosion shall be reseeded as soon as such areas are identified.

Seeding performed during hot and dry summer months shall be watered at a rate of 1 inch per week.

Common Problems / Concerns

- Insufficient topsoil or inadequately tilled, limed, and/ or fertilized seedbed results in poor establishment of vegetation.
- An overly high seeding rate of nurse crop (oat, rye or wheat) in the seed mixture results in over competition with the perennials.
- Seeding outside of seeding dates results in poor vegetation establishment and a decrease in plant hardiness.
- An inadequate rate of mulch results in poor germination and failure.

Specifications
for

Temporary Seeding

Table 7.8.1 Temporary Seeding Species Selection

Seeding Dates	Species	Lb./1000 ft2	Lb/Acre
March 1 to August 15	Oats Tall Fescue Annual Ryegrass	3 1 1	128 (4 Bushel) 40 40
	Perennial Ryegrass Tall Fescue Annual Ryegrass	1 1 1	40 40 40
	Annual Ryegrass Perennial Ryegrass Creeping Red Fescue Kentucky Bluegrass	1.25 3.25 0.4 0.4	55 142 17 17
	Oats Tall Fescue Annual Ryegrass	3 1 1	128 (3 bushel) 40 40
August 16th to November	Rye Tall Fescue Annual Ryegrass	3 1 1	112 (2 bushel) 40 40
	Wheat Tall Fescue Annual Ryegrass	3 1 1	120 (2 bushel) 40 40
	Perennial Rye Tall Fescue Annual Ryegrass	1 1 1	40 40 40
	Annual Ryegrass Perennial Ryegrass Creeping Red Fescue Kentucky Bluegrass	1.25 3.25 0.4 0.4	40 40 40
November 1 to Feb. 29	Use mulch only or dormant seeding		

Note: Other approved species may be substituted.

1. Structural erosion and sediment control practices such as diversions and sediment traps shall be installed and stabilized with temporary seeding prior to grading the rest of the construction site.
2. Temporary seed shall be applied between construction operations on soil that will not be graded or reworked for 21 days or greater. These idle areas shall be seeded within 7 days after grading.
3. The seedbed should be pulverized and loose to ensure the success of establishing vegetation. Temporary seeding should not be postponed if ideal seedbed preparation is not possible.
4. Soil Amendments—Temporary vegetation seeding rates shall establish adequate stands of vegetation, which may require the use of soil amendments. Base rates for lime and fertilizer shall be used.
5. Seeding Method—Seed shall be applied uniformly with a cyclone spreader, drill, cultipacker seeder, or hydroseeder. When feasible, seed that has been broadcast shall be covered by raking or dragging and then lightly tamped into place using a roller or cultipacker. If hydroseeding is used, the seed and fertilizer will be mixed on-site and the seeding shall be done immediately and without interruption.

Specifications
for
Temporary Seeding

Mulching Temporary Seeding

1. Applications of temporary seeding shall include mulch, which shall be applied during or immediately after seeding. Seedings made during optimum seeding dates on favorable, very flat soil conditions may not need mulch to achieve adequate stabilization.

2. Materials:

- Straw—If straw is used, it shall be unrotted small-grain straw applied at a rate of 2 tons per acre or 90 lbs./ 1,000 sq. ft. (2-3 bales)
- Hydroseeders—If wood cellulose fiber is used, it shall be used at 2000 lbs./ ac. or 46 lb./ 1,000-sq.-ft.
- Other—Other acceptable mulches include mulch mattings applied according to manufacturer's recommendations or wood chips applied at 6 ton/ ac.

3. Straw Mulch shall be anchored immediately to minimize loss by wind or water. Anchoring methods:

- Mechanical—A disk, crimper, or similar type tool shall be set straight to punch or anchor the mulch material into the soil. Straw mechanically anchored shall not be finely chopped but left to a length of approximately 6 inches.
- Mulch Netting—Netting shall be used according to the manufacturers recommendations. Netting may be necessary to hold mulch in place in areas of concentrated runoff and on critical slopes.
- Synthetic Binders—Synthetic binders such as Acrylic DLR (Agri-Tac), DCA-70, Petroset, Terra Track or equivalent may be used at rates recommended by the manufacturer.
- Wood-Cellulose Fiber—Wood-cellulose fiber binder shall be applied at a net dry wt. of 750 lb./ac. The wood-cellulose fiber shall be mixed with water and the mixture shall contain a maximum of 50 lb. / 100 gal.

7.9 Mulching

Description

A protective layer of mulch, usually of straw, applied to bare soil is used to abate erosion by shielding it from raindrop impact. Mulch also helps establish vegetation by conserving moisture and creating favorable conditions for seeds to germinate.

Conditions Where Practice Applies

Mulch should be used liberally throughout construction to limit the areas that are bare and susceptible to erosion. Mulch can be used in conjunction with seeding to establish vegetation or by itself to provide erosion control when the season does not allow grass to grow. Mulch and other vegetative practices must be applied on all disturbed portions of construction-sites that will not be re-disturbed for more than 21 days.

Design Criteria

See specifications for Mulching.

Maintenance

Additional mulching is necessary to cover exposed soil conditions when observed during routine maintenance inspections.

Common Problems / Concerns

The application of synthetic binders must be conducted in such a manner as to not be introduced into watercourses.

Weather considerations must be addressed to ensure the application of synthetic binders are not washed away and introduced into watercourses.

The use of a mulch cover is not recommended for areas, which will exhibit higher velocities than 3.5 feet/second. An erosion control matting is recommended for areas which will exhibit higher velocities.

Areas which have been mulched should be inspected and maintained if necessary every 7 days or within 24 hours of a rain event greater than or equal to 0.5 inches to ensure adequate protection.

Specifications
for

Mulching

1. Mulch and other appropriate vegetative practices shall be applied to disturbed areas within 7 days of grading if the area is to remain dormant (undisturbed) for more than 21 days or on areas and portions of the site which can be brought to final grade.
2. Mulch shall consist of one of the following:

- Straw - Straw shall be unrotted small grain straw applied at the rate of 2 tons/ac. or 90 lb./1,000 sq. ft. (two to three bales). The straw mulch shall be spread uniformly by hand or mechanically so the soil surface is covered. For uniform distribution of hand-spread mulch, divide area into approximately 1,000 sq.ft. sections and place two 45-lb. bales of straw in each section.
- Hydroseeders - Wood cellulose fiber should be used at 2,000 lb./ac. or 46 lb./1,000 sq. ft.
- Other - Acceptable mulches include mulch mattings and rolled erosion control products applied according to manufacturer's recommendations or wood mulch/chips applied at 10-20 tons/ac.

3. Mulch Anchoring - Mulch shall be anchored immediately to minimize loss by wind or runoff. The following are acceptable methods for anchoring mulch.

- Mechanical - Use a disk, crimper, or similar type tool set straight to punch or anchor the mulch material into the soil. Straw mechanically anchored shall not be finely chopped but be left generally longer than 6 inches.
- Mulch Nettings - Use according to the manufacturer's recommendations, following all placement and anchoring requirements. Use in areas of water concentration and steep slopes to hold mulch in place.
- Synthetic Binders - For straw mulch, synthetic binders such as Acrylic DLR (Agri-Tac), DCA-70, Petroset, Terra Tack or equal may be used at rates recommended by the manufacturer. All applications of Sythetic Binders must be conducted in such a manner where there is no contact with waters of the state.
- Wood Cellulose Fiber - Wood cellulose fiber may be used for anchoring straw. The fiber binder shall be applied at a net dry weight of 750 lb./acre. The wood cellulose fiber shall be mixed with water and the mixture shall contain a maximum of 50 lb./100 gal. of wood cellulose fiber.

7.10 Permanent Seeding

Description

Perennial vegetation is established on areas that will not be re-disturbed for periods longer than 12 months. Permanent seeding includes site preparation, seedbed preparation, planting seed, mulching, irrigation and maintenance.

Permanent vegetation is used to stabilize soil, reduce erosion, prevent sediment pollution, reduce runoff by promoting infiltration, and provide stormwater quality benefits offered by dense grass cover.

Conditions Where Practice Applies

Permanent seeding should be applied to:

- Any disturbed areas or portions of construction sites at final grade. Permanent seeding should not be delayed on any one portion of the site at final grade while construction on another portion of the site is being completed. Permanent seeding shall be completed in phases, if necessary.
- Areas subject to grading activities but will remain dormant for a year or more.

Planning Considerations

Vegetation controls erosion by reducing the velocity and the volume of overland flow and protects bare soil surface from raindrop impact. A healthy, dense turf promotes infiltration and reduces the amount of runoff. The establishment of quality vegetation requires selection of the right plant materials for the site, adequate soil amendments, careful seedbed preparation, and maintenance.

***Soil Compaction*—**Storm water quality and the amount of runoff both vary significantly with soil compaction. Non-compacted soils improve stormwater infiltration by promoting:

- dense vegetative growth;
- high soil infiltration & lower runoff rates;
- pollutant filtration, deposition & absorption; and
- beneficial biologic activity in the soil.

Construction activity creates highly compacted soils that restrict water infiltration and root growth. The best time for improving soil condition is during the establishment of permanent vegetation. It is highly recommended that subsoilers, plows, or other implements are specified as part of final seedbed preparation. Use discretion in slip-prone areas.

***Minimum Soil Conditions*—**Vegetation cannot be expected to stabilize soil that is unstable due to its texture, structure, water movement or excessively steep slope. The following minimum soil conditions are needed for the establishment and maintenance of a long-lived vegetative cover. If these conditions cannot be met, see the standards and specifications for Topsoiling.

- Soils must include enough fine-grained material to hold at least a moderate amount of available moisture.
- The soil must be free from material that is toxic or otherwise harmful to plant growth.

Design Criteria

See specifications for permanent seeding below.

Maintenance

1. Expect emergence within 4 to 28 days after seeding, with legumes typically following grasses. Check permanent seedlings within 4 to 6 weeks after planting. Look for:
    - Vigorous seedlings;
    - Uniform ground surface coverage with at least 30% growth density;
    - Uniformity with legumes and grasses well intermixed;
    - Green, not yellow, leaves. Perennials should remain green throughout the summer, at least at the plant bases.

2. Permanent seeding shall not be considered established for at least 1 full year from the time of planting. Inspect the seeding for soil erosion or plant loss during this first year. Repair bare and sparse areas. Fill gullies. Re-fertilize, re-seed, and re-mulch if required. Consider no-till planting. A minimum of 70% growth density, based on a visual inspection, must exist for an adequate permanent vegetative planting.

- If stand is inadequate or plant cover is patchy, identify the cause of failure and take corrective action: choice of plant materials, lime and fertilizer quantities, poor seedbed preparation, or weather. If vegetation fails to grow, have the soil tested to determine whether pH is in the correct range or nutrient deficiency is a problem.
- Depending on stand conditions, repair with complete seedbed preparation, then over-seed or re-seed.
- If it is the wrong time of year to plant desired species, over-seed with small grain cover crop to thicken the stand until timing is right to plant perennials or use temporary seeding. See Temporary Seeding standard.

3. Satisfactory establishment may require re-fertilizing the stand in the second growing season.
    - Do not fertilize cool season grasses in late May through July (i.e. Kentucky Bluegrass, Orchardgrass, Perrenial Ryegrass, Smooth Brome, Fescues, Timothy, Reed Canarygrass and Garrison Grass)
    - Grass that looks yellow may be nitrogen deficient. In lieu of a soil test, an application of 50 lbs. of N-P-K per acre in early spring will help cool season grasses compete against weeds or grow more successfully.
    - Do not use nitrogen fertilizer if the stand contains more than 20 percent legumes.

4. Long-term maintenance fertilization rates shall be established by following soil test recommendations or by using the rates shown in Table 2.

Table 7.10.1Maintenance for Permanent Seedings Fertilization and Mowing

Mixture	Formula	Lbs./ Acre	Lbs./1,000 sq.ft.	Time	Mowing
Creeping Red Fescue Ryegrass Kentucky Bluegrass	10-10-10	500	12	Fall, yearly or as needed	Not closer than 3”
Tall Fescue	10-10-10	500	12		Not closer than 4”
Turf-type Fescue	10-10-10	500	12		
Crown Vetch Fescue	0-20-20	400	10	Spring, yearly following establishment and every 4-7 years thereafter	Do not mow
Flat Pea Fescue	0-20-20	400	10		Do not mow

Note: Following soil test recommendations is preferred to fertilizer rates shown above.

5. Consider mowing after plants reach a height of 6 to 8 inches. Mow grasses tall, at least 3 inches in height and minimize compaction during the mowing process. Vegetation on structural practices such as embankments and grass-lined channels need to be mowed only to prevent woody plants from invading the stand.

Common Problems / Concerns

- Insufficient topsoil or inadequately tilled, limed, and/or fertilized seedbed - results in poor establishment of vegetation.
- Unsuitable species or seeding mixture - results in competition with the perennials.
- Nurse crop rate too high in the mixture - results in competition with the perennials.
- Seeding done at the wrong time of year - results in poor establishment of vegetation, also plant hardiness is significantly decreased.
- Mulch rate inadequate - results in poor germination and failure.

Specifications
for
Permanent Seeding

Site Preparation

1. Subsoiler, plow, or other implement shall be used to reduce soil compaction and allow maximum infiltration. (Maximizing infiltration will help control both runoff rate and water quality.) Subsoiling should be done when the soil moisture is low enough to allow the soil to crack or fracture. Subsoiling shall not be done on slip-prone areas where soil preparation should be limited to what is necessary for establishing vegetation.
2. The site shall be graded as needed to permit the use of conventional equipment for seedbed preparation and seeding.
3. Topsoil shall be applied where needed to establish vegetation.

Seedbed Preparation

1. Lime—Agricultural ground limestone shall be applied to acid soil as recommended by a soil test. In lieu of a soil test, lime shall be applied at the rate of 100 pounds per 1,000-sq. ft. or 2 tons per acre.
2. Fertilizer—Fertilizer shall be applied as recommended by a soil test. In place of a soil test, fertilizer shall be applied at a rate of 25 pounds per 1,000-sq. ft. or 1000 pounds per acre of a 10-10-10 or 12-12-12 analyses.
3. The lime and fertilizer shall be worked into the soil with a disk harrow, spring-tooth harrow, or other suitable field implement to a depth of 3 inches. On sloping land, the soil shall be worked on the contour.

Seeding Dates and Soil Conditions

Seeding should be done March 1 to May 31 or August 1 to September 30. If seeding occurs outside of the above-specified dates, additional mulch and irrigation may be required to ensure a minimum of 80% germination. Tillage for seedbed preparation should be done when the soil is dry enough to crumble and not form ribbons when compressed by hand. For winter seeding, see the following section on dormant seeding.

Dormant Seedings

1. Seedings should not be made from October 1 through November 20. During this period, the seeds are likely to germinate but probably will not be able to survive the winter.
2. The following methods may be used for “Dormant Seeding”:

- From October 1 through November 20, prepare the seedbed, add the required amounts of lime and fertilizer, then mulch and anchor. After November 20, and before March 15, broadcast the selected seed mixture. Increase the seeding rates by 50% for this type of seeding.
- From November 20 through March 15, when soil conditions permit, prepare the seedbed, lime and fertilize, apply the selected seed mixture, mulch and anchor. Increase the seeding rates by 50% for this type of seeding.
- Apply seed uniformly with a cyclone seeder, drill, cultipacker seeder, or hydro-seeder (slurry may include seed and fertilizer) on a firm, moist seedbed.
- Where feasible, except when a cultipacker type seeder is used, the seedbed should be firmed following seeding operations with a cultipacker, roller, or light drag. On sloping land, seeding operations should be on the contour where feasible.

Mulching

1. Mulch material shall be applied immediately after seeding. Dormant seeding shall be mulched. 100% of the ground surface shall be covered with an approved material.
2. Materials

- Straw—If straw is used it shall be unrotted small-grain straw applied at the rate of 2 tons per acre or 90 pounds (two to three bales) per 1,000-sq. ft. The mulch shall be spread uniformly by hand or mechanically applied so the soil surface is covered. For uniform distribution of hand-spread mulch, divide area into approximately 1,000-sq.-ft. sections and spread two 45-lb. bales of straw in each section.
- Hydroseeders—If wood cellulose fiber is used, it shall be applied at 2,000 lb./ac. or 46 lb./1,000 sq. ft.
- Other—Other acceptable mulches include rolled erosion control mattings or blankets applied according to manufacturer’s recommendations or wood chips applied at 6 tons per acre.

3. Straw and Mulch Anchoring Methods

Straw mulch shall be anchored immediately to minimize loss by wind or water.

- Mechanical—A disk, crimper, or similar type tool shall be set straight to punch or anchor the mulch material into the soil. Straw mechanically anchored shall not be finely chopped but, generally, be left longer than 6 inches.
- Mulch Netting—Netting shall be used according to the manufacturer's recommendations. Netting may be necessary to hold mulch in place in areas of concentrated runoff and on critical slopes.
- Asphalt Emulsion—Asphalt shall be applied as recommended by the manufacture or at the rate of 160 gallons per acre.
- Synthetic Binders—Synthetic binders such as Acrylic DLR (Agri-Tac), DCA-70, Petroset, Terra Tack or equivalent may be used at rates specified by the manufacturer.
- Wood Cellulose Fiber—Wood cellulose fiber shall be applied at a net dry weight of 750 pounds per acre. The wood cellulose fiber shall be mixed with water with the mixture containing a maximum of 50 pounds cellulose per 100 gallons of water.

Irrigation

Permanent seeding shall include irrigation to establish vegetation during dry weather or on adverse site conditions, which require adequate moisture for seed germination and plant growth.

Irrigation rates shall be monitored to prevent erosion and damage to seeded areas from excessive runoff.

Table 7.10.2 Permanent Seeding

Seed Mix	Seeding Rate		Notes:
	Lbs./acre	Lbs./1,000 Sq. Feet	
General Use			
Creeping Red Fescue Domestic Ryegrass Kentucky Bluegrass	20-40 10-20 20-40	1⁄2-1 1⁄4-1⁄2 1⁄2-1	For close mowing & for waterways with <2.0 ft/sec velocity
Tall Fescue	40-50	1-1 1⁄4	
Turf-type (dwarf) Fescue	90	2 1⁄4	
Steep Banks or Cut Slopes			
Tall Fescue	40-50	1-1 1⁄4	
Crown Vetch Tall Fescue	10-20 20-30	1⁄4-1⁄2 1⁄2-3⁄4	Do not seed later than August
Flat Pea Tall Fescue	20-25 20-30	1⁄2-3⁄4 1⁄2-3⁄4	Do not seed later than August
Road Ditches and Swales			
Tall Fescue	40-50	1-11⁄4	
Turf-type (Dwarf) Fescue Kentucky Bluegrass	 90 5	 2 1⁄4 0.1	
Lawns			
Kentucky Bluegrass Perennial Ryegrass	100-120	2 2	
Kentucky Bluegrass Creeping Red Fescue	100-120	2 1-1/2	For shaded areas

Note: Other approved seed species may be substituted.

7.11 Sodding

Description

Sodding utilizes rolls or mats of turf grass to provide immediate stabilization to bare soils. It is especially useful in highly erosive areas such as drainage ways and on slopes that will be mowed.

Conditions Where Practice Applies

Sod may be used where immediate cover is required or preferred, and where vegetation will be adequate stabilization such as minor swales, around drop inlets, and lawns.

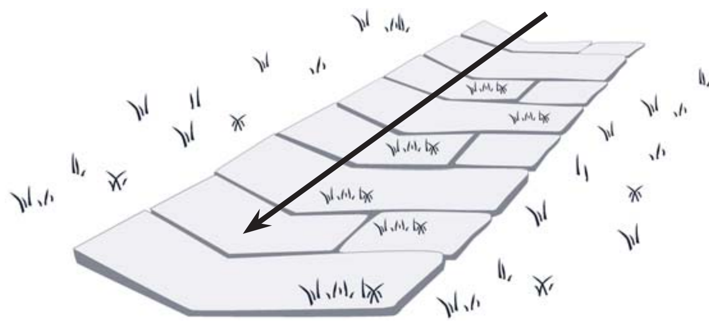
Design Criteria

These are provided in the specifications that follow.

Maintenance

Adequate moisture is the most important factor to establishing sod. Sod must be watered immediately after installation, daily during first week and as necessary for the remainder of the initial rooting period, usually 2-4 weeks. An adequate watering will moisten to a depth of 4-6 inches. Although watering needs and frequency may taper off after this period, sodded areas are not often independent of watering until their second season of growth. Most foot traffic should be limited and mowing withheld until the sod is firmly rooted.

Lay sod in a staggered brick like pattern



Utilizing sod in waterways

Common Problems / Concerns

- An inadequately prepared site or soils can cause inadequate rooting and establishment. Hard soils can cause runoff to occur between the sod and soil layers and poor establishment of the root system. The area should be adequately cleared of clods, debris, have sufficient topsoil and be moistened during dry periods.
- The placement of sod on frozen soil, or in freezing temperatures will result in failure to establish grass.
- Drying of sod during and immediately following the placement of sod will result in death of the sod.

References

Pound W., Street J., 1991. *Lawn Establishment Bulletin 546.* The Ohio State University.

Specifications
for

Sodding

Materials

1. Sod shall be harvested, delivered and installed within a period of 48 hours. Sod not transplanted within this period shall be inspected and approved prior to installation.
2. The sod shall be kept moist and covered during hauling and preparation for placement.
3. Sod shall be machine cut at a uniform soil thickness of 0.75 inches, plus or minus 0.25 inches, at the time of cutting. Measurements for thickness shall exclude top growth and thatch.

Site Preparation

1. A subsoiler, plow or other implement shall be used to reduce soil compaction and allow maximum infiltration. Maximizing infiltration will help control both runoff rate and water quality. Subsoiling shall not be conducted on slip-prone areas where soil preparation should be limited only to what is necessary for establishing vegetation.
2. The area shall be graded and topsoil spread where needed. (see Topsoiling)
3. Soil Amendments:

   Lime—Agricultural ground limestone shall be applied to acidic soils as recommended by a soil test. In lieu of a soil test, lime shall be applied at the rate of 100 lb./1,000 sq. ft. or 2 tons/ac.

   Fertilizer—Fertilizer shall be applied as recommended by a soil test. In lieu of a 2soil test fertilizer shall be applied at a rate of 12 lb./1,000 sq. ft. or 500 lb./ac. of 10-10-10 or 12-12-12 analysis.

   The lime and fertilizer shall be worked into the soil with a disk harrow, spring-tooth harrow, or other suitable field implement to a depth of 3 inches.
4. Before laying sod, the surface shall be uniformly graded and cleared of all debris, stones and clods larger than 3-in. diameter.

Sod Installation

1. During periods of excessively high temperatures, the soil shall be lightly irrigated immediately before laying the sod.
2. Sod shall not be placed on frozen soil.
3. The first row of sod shall be laid in a straight line with subsequent rows placed parallel to and tightly wedged against each other. Lateral joints shall be staggered in a brick-like pattern. Ensure that sod is not stretched or overlapped and that all joints are butted tight in order to prevent voids that would dry the roots.
4. On sloping areas where erosion may be a problem, sod shall be laid with the long edge parallel to the contour and with staggered joints. The sod shall be secured with pegs or staples.
5. As sodding is completed in any one section, the entire area shall be rolled or tamped to ensure solid contact of roots with the soil surface. Sod shall be watered immediately after rolling or tamping until the sod and soil surface below the sod are thoroughly wet. The operations of laying, tamping and irrigating for any piece of sod shall be completed within 8 hours.

Maintenance

1. In the absence of adequate rainfall, watering shall be performed daily or as often as necessary during the first week with sufficient quantities to maintain moist soil to a depth of 4-6 inches.
2. After the first week, sod shall be watered as necessary to maintain adequate moisture and ensure establishment.
3. The first mowing shall not be attempted until sod is firmly rooted.

7.12 Temporary Rolled Erosion Control Products (Erosion Control Matting)

Description

A Temporary Rolled Erosion Control Product (TRECP) is a degradable manufactured material used to stabilize easily eroded areas while vegetation becomes established. Temporary Rolled Erosion Control Products are degradable products composed of biologically, photo chemically or otherwise degradable materials. Temporary RECPs consist of erosion control netting, open weave textiles, and erosion control blankets and mattings. These products reduce soil erosion and assist vegetative growth by providing temporary cover from the erosive action of rainfall and runoff while providing soil-seed contact.

Condition where practice applies:

Temporary rolled erosion control products (matting or blankets) should be used on:

- Areas where erosion potential is high or a failure to establish vegetation is costly such as slopes greater than 3:1, constructed channels or stream banks
- Areas where establishing vegetation is difficult such as southern exposures or areas prone to drying
- Areas of concentrated flow, especially where flows exceeds 3.5 feet per second (e.g near culverts)
- Problem areas with highly erosive soils
- Areas where mulch is difficult to hold in place due to wind or water

Planning Considerations:

Temporary RECPs can be applied to critical or problem areas to enhance the erosion control as vegetation is being established. Although these materials add cost, they insure more immediate stability following construction reducing grading repairs and a faster greening of projects. Permanent non-degradable rolled erosion control products (turf reinforcement mats) are beyond the scope of this practice, but may be useful where design discharges or runoff exert velocities and shear stresses exceeding the ability of mature vegetation to withstand.

Temporary RECPs provide stable and rapid greening for areas conveying stormwater runoff. Care must be taken to choose the type of RECP, which is most appropriate for the specific needs of a project. Designers must take into account the vegetated and unvegetated velocities and sheer stresses in channel applications. With the abundance of soil stabilization products available, it is impossible to cover all the advantages, disadvantages and specifications of all manufactured RECPs. Therefore, as with many erosion control-type products, there is no substitute for a thorough understanding of the manufacturer's instructions and recommendations and a site visit by a product's designer or plan reviewer to verify appropriateness.

Temporary RECPs should be used to help establish vegetation on previously disturbed slopes - especially slopes of 3:1 or greater. The materials that compose the RECP will deteriorate over time. If used in permanent conveyance channels, designers should consider the system's resistance to erosion as it relates to the type of vegetation planted and the existing soil characteristics. As much as possible during establishment of vegetation, soil stabilization blankets should not be subjected to concentrated flows moving at greater than 3.5 feet/second.

Design Criteria

Choose a product that will provide the appropriate time period of protection. Allowable velocity range during vegetation establishment should be 3.5 feet per second or less.

Erosion Control Blankets - shall consist of photodegradable plastic netting or biodegradable natural fiber netting that covers and is entwined in a natural organic or man-made mulching material. The mulching material shall consist of wood fibers, wood excelsior, straw, coconut fiber, or man-made fibers, or a combination of the same. The blanket shall be of consistent thickness with the mulching material/fibers evenly distributed over its entire length. Mulching material/fibers must interlock or entwine to form a dense layer, which not only resists raindrop impact, but also will allow vegetation to penetrate the blanket. The mulching material degradation rate must be consistent with the designers desired slope protection time. Temporary Rolled Erosion Control Products (or erosion control blankets) shall meet the specifications that follow.

Table 7.12.1

Material	Maximum Length Of Protection
Straw	10-12 Months
Straw/Coconut	24 Months
Coconut	36 Months
Excelsior	36 Months

Erosion Control Netting - shall consist of a woven natural fiber or extruded geosynthetic mesh used as a component in the manufacture of RECPs, or separately as a temporary RECP to anchor loose fiber mulches.

Open Weave Textile - shall consist of processed natural or polymer yarns woven into a matrix, used to provide erosion control and facilitate vegetation establishment.

Maintenance:

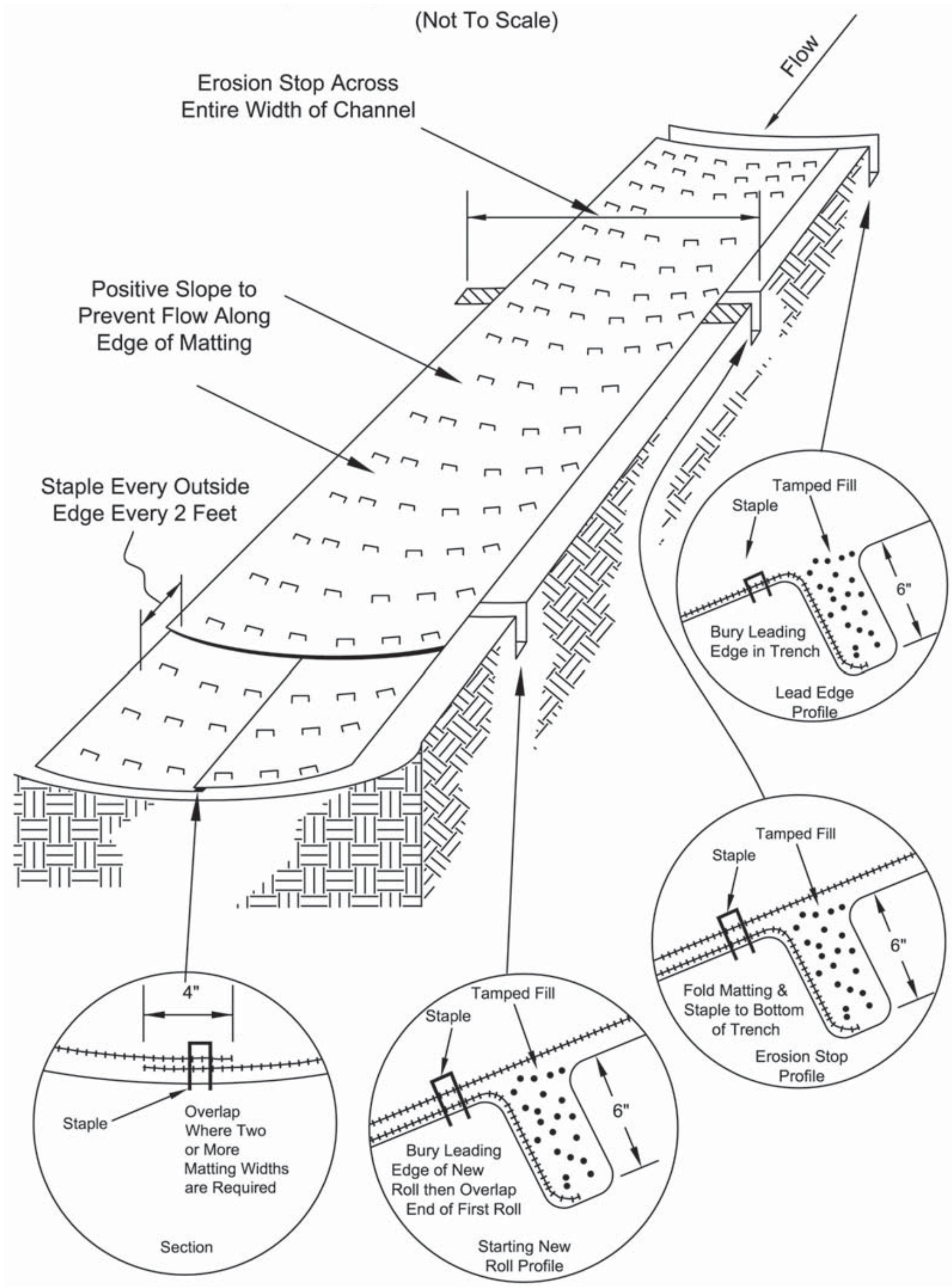
All RECPs should be inspected regularly after installation, especially after storms to check for erosion or undermining of the product. Make needed repairs immediately, addressing rills or gullies that have developed prior to replacing the RECP. In the case erosion repairs, assure that subsequent runoff across the area is dispersed or adequately spread.

Common Problems/Concerns:

- Manufacturer's selection and installation recommendations not followed. Results in failure of the RECP.
- Poor contact between soil and the RECP. Results in erosion below the RECP and lower seed germination rates, causing failure.
- Proper stapling guidelines not followed. Results in movement or displacement of RECP.
- Erosion check slots are not used. Results in erosion under the RECP, causing failure.
- Unstable slopes that result in RECP or slope failure. Determine cause of slope failure, correct, and reinstall RECP
- In channels, the width of RECP used is not sufficient, this causes water to flow along the sides of RECP causing erosion. Install RECP up side slopes of ditch line as well as the bottom.

Specifications
for

Temporary Rolled Erosion Control Product



Specifications
for

Temporary Rolled Erosion Control Product

1. Channel/Slope Soil Preparation Grade and compact area of installation, preparing seedbed by loosening 2”-3” of topsoil above final grade. Incorporate amendments such as lime and fertilizer into soil. Remove all rocks, clods, vegetation or other debris so that installed RECP will have direct contact with the soil surface.
2. Channel/Slope Seeding Apply seed to soil surface prior to installation. All check slots, anchor trenches, and other disturbed areas must be reseeded. Refer to the Permanent Seeding specification for seeding recommendations.

Slope Installation

3. Excavate top and bottom trenches (12”x6”). Intermittent erosion check slots (6”x6”) may be required based on slope length. Excavate top anchor trench 2’ x 3’ over crest of the slope.
4. If intermittent erosion check slots are required, install RECP in 6”x6” slot at a maximum of 30’ centers or the mid point of the slope. RECP should be stapled into trench on 12” centers.
5. Install RECP in top anchor trench, anchor on 12” spacings, backfill and compact soil.
6. Unroll RECP down slope with adjacent rolls overlapped a minimum of 3”. Anchor the seam every 18”. Lay the RECP loose to maintain direct soil contact, do not pull taught.
7. Overlap roll ends a minimum of 12” with upslope RECP on top for a shingle effect. Begin all new rolls in an erosion check slot if required, double anchor across roll every 12”.
8. Install RECP in bottom anchor trench (12”x6”), anchor every 12”. Place all other staples throughout slope at 1 to 2.5 per square yard dependant on slope. Refer to manufacturer’s anchor guide.

Channel Installation

9. Excavate initial anchor trench (12”x6”) across the lower end of the project area.
10. Excavate intermittent check slots (6”x6”) across the channel at 30’ intervals along the channel.
11. Excavate longitudinal channel anchor slots (4”x4”) along both sides of the channel to bury the edges. Whenever possible extend the RECP 2’-3’ above the crest of channel side slopes.
12. Install RECP in initial anchor trench (downstream) anchor every 12”, backfill and compact soil.
13. Roll out RECP beginning in the center of the channel toward the intermittent check slot. Do not pull taught. Unroll adjacent rolls upstream with a 3” minimum overlap (anchor every 18”) and up each channel side slope.
14. At top of channel side slopes install RECP in the longitudinal anchor slots, anchor every 18”.
15. Install RECP in intermittent check slots. Lay into trench and secure with anchors every 12”, backfill with soil and compact.
16. Overlap roll ends a minimum of 12” with upstream RECP on top for a shingling effect. Begin all new rolls in an intermittent check slot, double anchored every 12”.
17. Install upstream end in a terminal anchor trench (12”x6”); anchor every 12”, backfill and compact.
18. Complete anchoring throughout channel at 2.5 per square yard using suitable ground anchoring devices (U shaped wire staples, metal geotextile pins, plastic stakes, and triangular wooden stakes). Anchors should be of sufficient length to resist pullout. Longer anchors may be required in loose sandy or gravelly soils.

7.13 Turf Reinforcement Matting (Permanent Rolled Erosion Control Products)

Description

Turf reinforcement matting (TRM) is a permanent, non-degradable rolled erosion control product used to reinforce natural soil and vegetated growth with synthetic materials to prevent erosion and maintain the durability of vegetated areas. Turf reinforcement is generally an interwoven material applied to areas where natural vegetation alone is not sufficient to withstand expected flow conditions or to provide sufficient long-term erosion protection.

Condition where practice applies

Turf reinforcement matting (TRM) is applicable on:

- Critical areas or slopes (up to 1:1) where erosion potential is high
- Water conveyances subject to higher shear stresses and velocities (> 3.5 fps) than normally advisable for vegetated channels
- Area subject to limited scour
- slopes areas where vegetation has been disturbed and soil replaced

Turf reinforcement matting is not appropriate for areas which will be constantly inundated with water and therefore unable to establish adequate vegetation.

Planning Considerations

Turf reinforcement matting provides 3-dimensional matrix for root growth that increases the vegetation's ability to resist the shear forces of moving water. TRMs are commonly used in channels designed to carry stormwater runoff. Site designers should follow manufacturer's recommendations on maximum permissible shear stresses and flow velocities. These recommendations change according to the development of the vegetation. They should be considered for at least these three stages during design: 1) no vegetation (soil and TRM); vegetation at 50% cover; and fully established vegetation.

During establishment velocities should not exceed 10 feet per second. Depending upon the manufacturer's recommendations, velocities may be increased up to 18 fps and 8 pounds of shear stress, or greater, once completely vegetated. Specific guidance regarding product limitations for turf reinforcement mats designed for permanent application must be sought from the manufacturers. While velocity may be useful for slope applications, calculating permissible shear stress is necessary and more appropriate for channel applications.

With many manufacturers' products available, it is impossible to cover all the advantages, disadvantages and specifications of each. Therefore, as with many erosion control products, there is no substitute for a thorough understanding of the manufacturer's instructions and recommendations and site visits by the designer to verify appropriateness.

Design Criteria

Turf reinforcement matting generally has an allowable velocity range during vegetation establishment of less than or equal to 0 – 10 feet per second, although this will vary according to each manufacturer's product.

Materials – shall consist of a 100% non-degradable synthetic material with a three-dimensional geomatrix of nylon, polyethylene, or randomly oriented monofilaments, forming a mat. The product should contain an ultra violet (UV) stabilizer to ensure longevity. Selection of appropriate matting materials along with proper installation and vegetation establishment are critical factors in the success of this practice.

Soil shall be prepared Make the soil surface is stable, firm, and free of rocks and other obstructions. Install the turf reinforcement matting according to the manufacturer's published installation guidelines or the following specifications contains in this practice whichever is more restrictive.

Turf reinforcement matting applications require the TRM material first, applying seed the TRM is required. If soil in-filling is required, install TRM, apply seed, and lightly brush or rake 0.3 to 0.7 in. (8 to 18 mm) of topsoil into the voids in the TRM to fill the product thickness.

Maintenance

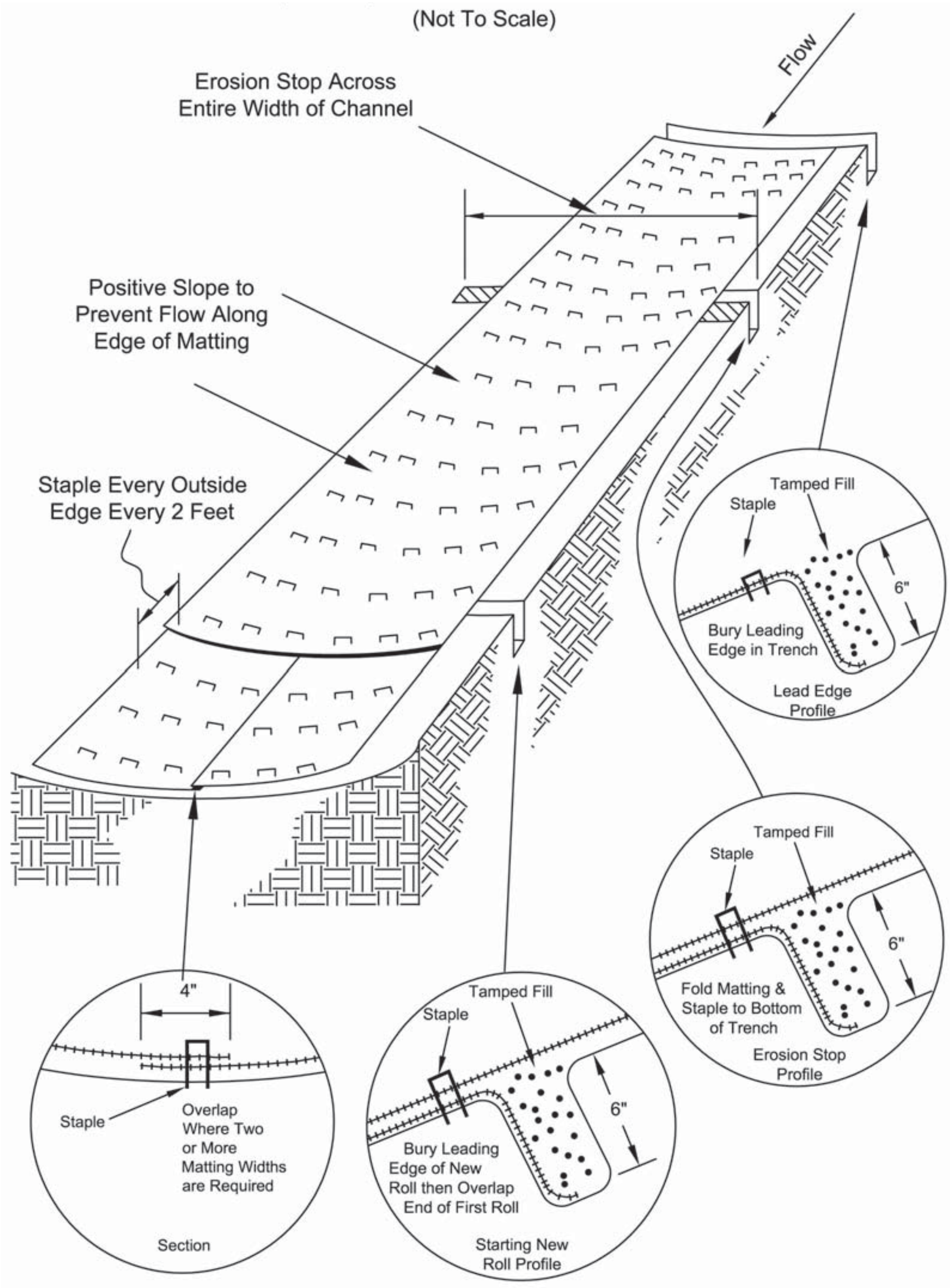
All TRMs should be inspected regularly after installation, especially after storms to check for erosion or undermining of the product. Make needed repairs immediately, addressing rills or gullies that have developed prior to replacing the TRM. In the case erosion repairs, assure that subsequent runoff across the area is dispersed or adequately spread.

Common Problems / Concerns

- Manufacturer's installation recommendations not followed. Results in failure of the TRM.
- Poor contact between soil and the TRM. Results in erosion below the TRM and lower seed germination rates, causing failure.
- Proper stapling guidelines not followed. Results in movement or displacement of TRM.
- Erosion check slots are not used. Results in erosion under the TRM, causing failure.
- Unstable slopes that result in TRM or slope failure. Determine cause of slope failure, correct, and reinstall TRM
- In channels, the width of TRM used is not sufficient, this causes water to flow along the sides of TRM causing erosion. Install TRM up side slopes of ditch line as well as the bottom.

Specifications
for

Turf Reinforcement Matting



Specifications
for

Turf Reinforcement Matting

1. Channel/Slope Soil Preparation Grade and compact area of installation, preparing seedbed by loosening 2”-3” of topsoil above final grade. Incorporate amendments such as lime and fertilizer into soil. Remove all rocks, clods, vegetation or other debris so that installed TRM will have direct contact with the soil surface.
2. Channel/Slope Seeding Apply seed to soil surface prior to installation. All check slots, anchor trenches, and other disturbed areas must be reseeded. Refer to the Permanent Seeding specification for seeding recommendations.

Slope Installation

3. Excavate top and bottom trenches (12”x6”). Intermittent erosion check slots (6”x6”) may be required based on slope length. Excavate top anchor trench 2’ x 3’ over crest of the slope.
4. If intermittent erosion check slots are required install TRM in 6”x6” slot at a maximum of 30’ centers or the mid point of the slope. TRM should be stapled into trench on 12” centers.
5. Install TRM in top anchor trench, anchor on 12” spacings, backfill and compact soil.
6. Unroll TRM down slope with adjacent rolls overlapped a minimum of 3”. Anchor the seam every 18”. Lay the TRM loose to maintain direct soil contact, do not pull taught.
7. Overlap roll ends a minimum of 12” with upslope TRM on top for a shingle effect. Begin all new rolls in an erosion check slot if required, double anchor across roll every 12”.
8. Install TRM in bottom anchor trench (12”x6”), anchor every 12”. Place all other staples throughout slope at 1 to 2.5 per square yard dependant on slope. Refer to manufacturer’s anchor guide.

Channel Installation

9. Excavate initial anchor trench (12”x6”) across the lower end of the project area.
10. Excavate intermittent check slots (6”x6”) across the channel at 30’ intervals along the channel.
11. Excavate longitudinal channel anchor slots (4”x4”) along both sides of the channel to bury the edges. Whenever possible extend the TRM 2’-3’ above the crest of channel side slopes.
12. Install TRM in initial anchor trench (downstream) anchor every 12”, backfill and compact soil.
13. Roll out TRM beginning in the center of the channel toward the intermittent check slot. Do not pull taught. Unroll adjacent rolls upstream with a 3” minimum overlap (anchor every 18”) and up each channel side slope.
14. At top of channel side slopes install TRM in the longitudinal anchor slots, anchor every 18”.
15. Install TRM in intermittent check slots. Lay into trench and secure with anchors every 12”, backfill with soil and compact.
16. Overlap roll ends a minimum of 12” with upstream TRM on top for a shingling effect. Begin all new rolls in an intermittent check slot, double anchored every 12”.
17. Install upstream end in a terminal anchor trench (12”x6”); anchor every 12”, backfill and compact.
18. Complete anchoring throughout channel at 2.5 per square yard using suitable ground anchoring devices (U shaped wire staples, metal geotextile pins, plastic stakes, and triangular wooden stakes). Anchors should be of sufficient length to resist pullout. Longer anchors may be required in loose sandy or gravelly soils.

CHAPTER 8

Additional Construction Site Pollution Prevention & Small Construction Site Controls

This chapter focuses on two categories of pollution control that are often overlooked during development. First, there are potential sources of pollution present during construction, such as construction wastes, leftover toxic materials or fuels. Properly handling these and other materials is important to maintaining clean air, water and soil resources. The Non-sediment Pollution Control practice gives information on properly handling these materials as well as what materials may be regulated.

The second often-overlooked source of pollution during development is the small construction site. Individual lots sold from a larger development project or a small parcel under development can be the site of intensive construction. Since space is usually limited and runoff is often effectively conveyed from these sites by storm sewers and swales, they can be significant sources of mud and sediment. The Small Construction Site Controls practice in this chapter gives information on typical controls and sequencing to control erosion and sediment from these areas.

8.1 Additional Construction Site Pollution Controls

Description

Although sediment is the primary pollutant of concern resulting from construction activity, other pollutants need to be considered as well. These include petrochemicals: fuel, oil, and asphalt; and construction chemicals and materials: paints, solvents, fertilizer, soil additives, concrete wash water, etc. Also included are solid wastes and construction debris. Keeping these substances from polluting runoff can be accomplished to a large extent through good housekeeping and following the manufacturer's recommendations for their use and disposal.

Condition Where Practice Applies

Wastes generated by construction activities (i.e. construction materials such as paints, solvents, fuels, concrete, wood, etc.) must be disposed of in accordance with ORC 3734 and ORC 3714. Hazardous and toxic substances are used on virtually all construction-sites. Good management of these substances is always needed.

Planning Considerations

Good erosion and sediment control will prevent some pollutants in addition to sediment from leaving the site; however, pollutants carried in solution or as surface films on runoff water will be carried through most erosion and sediment control practices. These pollutants become nearly impossible to control once carried offsite in runoff. Adding to the problem is the fact that construction wastes, many containing toxic chemicals, are routinely buried on-site, dumped on the ground, poured down a storm drain, or disposed of with construction debris. So while typical erosion and sediment-control practices are important for controlling other pollutants, additional preventative measures are needed.

Reducing pollutants other than sediments depends heavily on construction personnel and how they carry out their operations. To help facilitate this, plans should contain standard notes clearly stating requirements to contractors. It also may be appropriate to include requirements for specific provisions for hazardous materials storage, handling and disposal.

Requirements

1. **Educate Construction Personnel**, including subcontractors who may use or handle hazardous or toxic materials, making them aware of the following general guidelines:

Disposal and Handling of Hazardous and Other Construction Waste	
DO:	• Prevent spills • Use products up • Follow label directions for disposal • Remove lids from empty bottles and cans when disposing in trash • Recycle wastes whenever possible
DON'T	• Don't pour into waterways, storm drains or onto the ground • Don't pour down the sink, floor drain or septic tanks • Don't bury chemicals or containers • Don't burn chemicals or containers • Don't mix chemicals together

2. **Waste disposal containers** shall be provided for the proper collection of all waste material including construction debris, sanitary garbage, petroleum products and any hazardous materials to be used on-site. Containers shall be covered and not leaking. All waste material shall be disposed of at facilities approved for that material. Construction Demolition and Debris (CD&D) waste must be disposed of in accordance with ORC 3714 at an approved Ohio EPA CD&D landfill.

3. **No construction related waste materials are to be buried on-site.** By exception, clean fill (bricks, hardened concrete, soil) may be utilized in a way that does not encroach upon natural wetlands, streams or their floodplains. Filling of stream side areas is Fill may not result in the contamination of waters of the state. unless prohibited by local ordinance or zoning.

4. **Construction and Demolition Debris (CD&D) Disposal.** CD&D waste must be disposed of in accordance with ORC 3714 at an approved Ohio EPA CD&D landfill. CD&D waste is defined as all materials attached to a structure, which is being demolished (for materials containing asbestos see Item 12).

5. **Handling Construction Chemicals.** Mixing, pumping, transferring or other handling of construction chemicals such as fertilizer, lime, asphalt, concrete drying compounds, and all other potentially hazardous materials shall be performed in an area away from any watercourse, ditch or storm drain.

6. **Equipment Fueling and Maintenance,** oil changing, etc., shall be performed away from watercourses, ditches or storm drains, in an area designated for that purpose. The designated area shall be equipped for recycling oil and catching spills. Secondary containment shall be provided for all fuel oil storage tanks. These areas must be inspected every seven days and within 24 hrs. of a 0.5 inch or greater rain event to ensure there are no exposed materials which would contaminate storm water. Site operators must be aware that Spill Prevention Control and Countermeasures (SPCC) requirements may apply. An SPCC plan is required for sites with one single aboveground tank of 660 gallons or more, accumulative aboveground storage of 1330 gallons or more, or 42,000 gallons of underground storage. Soils that have become contaminated must be disposed of accordance with Item 8 "Contaminated Soils".

7. **Concrete Wash Water/Wash Outs.** Concrete wash water shall not be allowed to flow to streams, ditches, storm drains, or any other water conveyance. A sump or pit with no potential for discharge shall be constructed if needed to contain concrete wash water. Field tile or other subsurface drainage structures within 10 ft. of the sump shall be cut and plugged. For small projects, truck chutes may be rinsed on the lot away from any water conveyances.

8. **Contaminated Soils**. If substances such as oil, diesel fuel, hydraulic fluid, antifreeze, etc. are spilled, leaked, or released onto the soil, the soil should be dug up and disposed of at licensed sanitary landfill or other approved petroleum contaminated soil remediation facility (not a construction/demolition debris landfill). Please be aware that storm water run off associated with contaminated soils are not authorized under Ohio EPA's General Storm Water Permit associated with Construction Activities. In the event there are large extensive areas of contaminated soils additional measures above and beyond the conditions of Ohio EPA's General Construction Storm Water Permit will be required. Depending on the extent of contamination, additional treatment and/or collection and disposal may be required. All storm water discharges associated with the contaminated soils must be authorized under an alternate NPDES (National Pollutant Discharge Elimination System) Permit.

9. **Spill Reporting Requirements:** Spills on pavement shall be absorbed with sawdust, kitty litter or other absorbant material and disposed of with the trash at a licensed sanitary landfill. Hazardous or industrial wastes such as most solvents, gasoline, oil-based paints, and cement curing compounds require special handling. Spills shall be reported to Ohio EPA (1-800-282-9378). Spills of 25 gallons or more of petroleum products shall be reported to Ohio EPA (1-800-282-9378), the local fire department, and the Local Emergency Planning Committee within 30 min. of the discovery of the release. All spills, which result in contact with waters of the state, must be reported to OHIO EPA's Hotline.

10. **Open Burning**. No materials may be burned which contain rubber, grease, asphalt, or petroleum products such as tires, cars, autoparts, plastics or plastic coated wire. (See OAC 3745-19) Open burning is not allowed in restricted areas. Restricted areas are defined as: 1) within corporation limits; 2) within 1000 feet outside a municipal corporation having a population of 1000 to 10,000; and 3) a one mile zone outside of a

corporation of 10, 000 or more. Outside a restricted area, no open burning can take place within a 1000 feet of an inhabited building located off the property where the fire is set. Open burning is permissible in a restricted area for the following activities: heating tar, welding and acetylene torches, smudge pots and similar occupational needs, and heating for warmth or outdoor barbeques. Outside of restricted areas, open burning is permissible for landscape wastes (plant material), land-clearing wastes (plant material, with prior written permission from Ohio EPA), and agricultural wastes (material generated by crop, horticultural, or livestock production practices. This includes fence posts and scrap lumber, but not buildings).

11. **Dust Control/Suppressants.** Dust control is required to prevent nuisance conditions. Dust controls must be used in accordance with the manufacturer's specifications and not be applied in a manner, which would result in a discharge to waters of the state. Isolation distances from bridges, catch basins, and other drainageways must be observed. Application (excluding water) may not occur when precipitation is imminent as noted in the short term forecast. Used oil may not be applied for dust control.

12. **Other Air Permitting Requirements:** All contractors and sub contractors must be made aware that certain activities associated with construction will require air permits. Activities including but not limited to mobile concrete batch plants, mobile asphalt plants, concrete crushers, large generators, etc., will require specific Ohio EPA Air Permits for installation and operation. These activities must seek authorization from the corresponding district of Ohio EPA. Notification for Restoration and Demolition must be submitted to Ohio EPA for all commercial sites to determine if asbestos corrective actions are required.

13. **Process Waste Water/Leachate Management.** All contractors shall be made aware that Ohio EPA's Construction General Permit only allows the discharge of storm water. Other waste streams/discharges including but not limited to vehicle and/or equipment washing, leachate associated with on-site waste disposal, concrete wash outs, etc are a process wastewater. They are not authorized for discharge under the General Storm Water Permit associated with Construction Activities. All process wastewaters must be collected and properly disposed at an approved disposal facility. In the event there are leachate outbreaks associated with onsite disposal, measures must be taken to isolate this discharge for collection and proper disposal. Investigative measures and corrective actions must be implemented to identify and eliminate the source of all leachate outbreaks.

14. **Permit To Install (PTI) Requirements:** All contractors and sub contractors must be made aware that a PTI must be submitted and approved by Ohio EPA prior to the construction of all centralized sanitary systems, including sewer extensions, and sewerage systems (except those serving one, two, and three family dwellings) and potable water lines. The issuance of an Ohio EPA Construction General Storm Water Permit does not authorize the installation of any sewerage system where Ohio EPA has not approved a PTI.

Specifications
for

Additional Construction Site Pollution Controls

1. Construction personnel, including subcontractors who may use or handle hazardous or toxic materials, shall be made aware of the following general guidelines regarding disposal and handling of hazardous and construction wastes:
   - Prevent spills
   - Use products up
   - Follow label directions for disposal
   - Remove lids from empty bottles and cans when disposing in trash
   - Recycle wastes whenever possible
   - Don't pour into waterways, storm drains or onto the ground
   - Don't pour down the sink, floor drain or septic tanks
   - Don't bury chemicals or containers
   - Don't burn chemicals or containers
   - Don't mix chemicals together
2. **Containers shall be provided for the proper collection of all waste material including construction debris, trash, petroleum products and any hazardous materials used on-site.** Containers shall be covered and not leaking. All waste material shall be disposed of at facilities approved for that material. Construction Demolition and Debris (CD&D) waste must be disposed of at an Ohio EPA approved CD&D landfill.
3. **No construction related waste materials are to be buried on-site.** By exception, clean fill (bricks, hardened concrete, soil) may be utilized in a way which does not encroach upon natural wetlands, streams or floodplains or result in the contamination of waters of the state.
4. **Handling Construction Chemicals.** Mixing, pumping, transferring or other handling of construction chemicals such as fertilizer, lime, asphalt, concrete drying compounds, and all other potentially hazardous materials shall be performed in an area away from any watercourse, ditch or storm drain.
5. **Equipment Fueling and Maintenance,** oil changing, etc., shall be performed away from watercourses, ditches or storm drains, in an area designated for that purpose. The designated area shall be equipped for recycling oil and catching spills. Secondary containment shall be provided for all fuel oil storage tanks. These areas must be inspected every seven days and within 24 hrs. of a 0.5 inch or greater rain event to ensure there are no exposed materials which would contaminate storm water. Site operators must be aware that Spill Prevention Control and Countermeasures (SPCC) requirements may apply. An SPCC plan is required for sites with one single above ground tank of 660

gallons or more, accumulative above ground storage of 1330 gallons or more, or 42,000 gallons of underground storage. Contaminated soils must be disposed of in accordance with Item 8.

6. **Concrete Wash Water** shall not be allowed to flow to streams, ditches, storm drains, or any other water conveyance. A sump or pit with no potential for discharge shall be constructed if needed to contain concrete wash water. Field tile or other subsurface drainage structures within 10 ft. of the sump shall be cut and plugged. For small projects, truck chutes may be rinsed away from any water conveyances.

7. **Spill Reporting Requirements:** Spills on pavement shall be absorbed with sawdust or kitty litter and disposed of with the trash at a licensed sanitary landfill. Hazardous or industrial wastes such as most solvents, gasoline, oil-based paints, and cement curing compounds require special handling. Spills shall be reported to Ohio EPA (1-800-282-9378). Spills of 25 gallons or more of petroleum products shall be reported to Ohio EPA, the local fire department, and the Local Emergency Planning Committee within 30 min. of the discovery of the release. All spills which contact waters of the state must be reported to Ohio EPA.

8. **Contaminated Soils.** If substances such as oil, diesel fuel, hydraulic fluid, antifreeze, etc. are spilled, leaked, or released onto the soil, the soil should be dug up and disposed of at licensed sanitary landfill or other approved petroleum contaminated soil remediation facility. (not a construction/demolition debris landfill). Note that storm water run off associated with contaminated soils are not be authorized under Ohio EPA's General Storm Water Permit associated with Construction Activities.

9. **Open Burning.** No materials containing rubber, grease, asphalt, or petroleum products, such as tires, autoparts, plastics or plastic coated wire may be burned (OAC 3745-19). Open burning is not allowed in restricted areas, which are defined as: 1) within corporation limits; 2) within 1000 feet outside a municipal corporation having a population of 1000 to 10,000; and 3) a one mile zone outside of a corporation of 10, 000 or more. Outside of restricted areas, no open burning is allowed within a 1000 feet of an inhabited building on another property. Open burning is permissible in a restricted area for: heating tar, welding, smudge pots and similar occupational needs, and heating for warmth or outdoor barbeques. Outside of restricted areas, open burning is permissible for landscape or land-clearing wastes (plant material, with prior written permission from Ohio EPA), and agricultural wastes, excluding buildings.

10. **Dust Control or dust suppressants** shall be used to prevent nuisance conditions, in accordance with the manufacturer's specifications and in a manner, which prevent a discharge to waters of the state. Sufficient distance must be provided between applications and nearby bridges, catch basins, and other waterways. Application (excluding water) may not occur when rain is imminent as noted in the short term forecast. Used oil may not be applied for dust control.

11. **Other Air Permitting Requirements:** Certain activities associated with construction will require air permits including but not limited to: mobile concrete batch plants, mobile asphalt plants, concrete crushers, large generators, etc. These activities will require specific Ohio EPA Air Permits for installation and operation. Operators must seek authorization from the corresponding district of Ohio EPA. For demolition of all

commercial sites, a Notification for Restoration and Demolition must be submitted to Ohio EPA to determine if asbestos corrective actions are required.

12. **Process Waste Water/Leachate Management.** Ohio EPA's Construction General Permit only allows the discharge of storm water and does not include other waste streams/discharges such as vehicle and/or equipment washing, on-site septic leachate concrete wash outs, which are considered process wastewaters. All process wastewaters must be collected and properly disposed at an approved disposal facility. In the event, leachate or septage is discharged; it must be isolated for collection and proper disposal and corrective actions taken to eliminate the source of waste water.

13. **A Permit To Install (PTI)** is required prior to the construction of all centralized sanitary systems, including sewer extensions, and sewerage systems (except those serving one, two, and three family dwellings) and potable water lines. Plans must be submitted and approved by Ohio EPA. Issuance of an Ohio EPA Construction General Storm Water Permit does not authorize the installation of any sewerage system where Ohio EPA has not approved a PTI.

8.2 Small Construction Site Controls

Description

These are general pollution prevention practices appropriate for small projects or for construction done by separate builders, but which still is part of a larger common plan of development.

Conditions Where Practice Applies

This standard applies most commonly to builders of single-family homes on lots that have been purchased from a land developer who, typically, has constructed roads and utilities. This standard also may be used for projects too small or short term to justify developing a plan defining specific pollution-control structures. Small short-term projects generally are an acre or less and do not last more than a few weeks.

Planning Considerations

Single-family housing development creates a challenging condition for controlling sediment pollution during construction. First, during single-family residential development, the highest sediment pollution rates typically occur in the home-building phase. This is due to the intensity of activity and the fact that the drainage system is usually functional at this point. Second, it is difficult to determine who is responsible for erosion and sediment control as builders purchase lots from the land developer and as numerous contractors and subcontractors become involved.

The initial storm water pollution prevention plan can do much to reduce the amount of sediment pollution produced throughout single-family housing development. The control practices that can be used on a development-wide scale are much more effective than what can be accomplished on individual lots. Sediment pollution can be significantly reduced if the initial plan is designed to remain in effect well into the building of individual homes. The initial sediment-control system of settling ponds, diversions, etc., should remain functional as far into the home-building phase as is feasible. The initial plan also should describe practices individual builders must implement on individual lots as is described in the following specifications.

Design Criteria

Implement the storm water pollution prevention plan. In Ohio, a storm water pollution prevention plan (SWPPP) is required for any lot that is part of a development plan, which exceeds 1 acre of total disturbance. Although this practice describes that which applies to small lot building sites, the actual storm water pollution prevention plan may be included in a larger parcel plan, such as that for a residential subdivision. Generally the storm water pollution prevention plan includes all the drawings, notes and instructions needed to control erosion, capture sediment and control pollutants from storm water during and after construction and should convey to each lot owner or developer the responsibilities for controlling pollution from their portion of the development.

The following items should be located on a plan view or sample plan view of the lot:

- *Locations of surface water resources.* Streams or wetlands that are on the lot or nearby should be shown.
- *Areas to be marked off and left undisturbed.* This should include setbacks from wetlands or streams, the representative spread of the limbs of trees to be protected (dripline) or areas that will be left in vegetation and at the original grade during construction.
- *Limits of grading.* This is typically a line that represents a realistic extent of the work area on the lot.
- *Footprint of the building and site improvements.*
- *Sediment controls appropriate to the existing and future drainage of the lot.*
- *Location(s) of construction entrance.*
- *Locations of stockpiles for topsoil and excavated subsoil.*
- *Areas that will require temporary and permanent seedings.* While this area is largely the same as the limits of grading, the timing of seedings will be dependent on the timing of work on the lot and must be represented in the Construction Sequence.

Principles of pollution prevention on small building lots

1. Leave pre-existing vegetation on the building lot for as long as construction operations allow.

   In many cases, portions of the lot will not undergo grading or construction operations and can be left indefinitely if they are adequately marked in the field. Provided these areas are well vegetated, they will limit the amount of sediment in runoff and may act as filter strips, treating runoff before it leaves the lot.

   Clearing shall be done so that only active working areas are bare. Combining existing vegetation, such as grass, with a sediment barrier such as a silt fence increases sediment control effectiveness and reduces the need for maintenance.

2. Temporary seed and/or mulch shall be liberally applied to areas, such as stockpiles and rough graded areas, that are bare and not actively being worked. This shall apply to areas that will not be reworked for 21 days or more.

   Temporary seeding and mulch provides fast cover for bare soils to prevent erosion. Most small lots will present numerous opportunities to reseed temporary cover. Having seed and straw materials available prior to excavation or rough grading work stopping is key to good cover. Seedings made immediately after grading operations are typically the most successful. Soils that remain exposed and are first eroded will be more difficult area to establish grass cover.

   The Temporary Seeding practice in Chapter 7 (Stabilization) contains more information regarding seeding methods and amendments. Below are recommended seeding mixes and rates that should be incorporated into pollution prevention plans. Straw mulch should be applied at the rate of 90 pounds per 1000 square feet (approximate 2-3 bales).

Table 8.2.1 Temporary Seeding Species Selection

Seeding Dates	Species	Lb./1000 ft2	Lb/Acre
March 1 to August 15	Oats Tall Fescue Annual Ryegrass	3 1 1	128 (4 Bushel) 40 40
	Perennial Ryegrass Tall Fescue Annual Ryegrass	1 1 1	40 40 40
	Annual Ryegrass Perennial Ryegrass Creeping Red Fescue Kentucky Bluegrass	1.25 3.25 0.4 0.4	55 142 17 17
	Oats Tall Fescue Annual Ryegrass	3 1 1	128 (3 bushel) 40 40
August 16th to November 1	Rye Tall Fescue Annual Ryegrass	3 1 1	112 (2 bushel) 40 40
	Wheat Tall Fescue Annual Ryegrass	3 1 1	120 (2 bushel) 40 40
	Perennial Rye Tall Fescue Annual Ryegrass	1 1 1	40 40 40
	Annual Ryegrass Perennial Ryegrass Creeping Red Fescue Kentucky Bluegrass	1.25 3.25 0.4 0.4	40 40 40 17
November 1 to February 29	Use mulch only or dormant seeding		

Note: Other approved species may be substituted.

3. Stockpiles created from basement excavation and grading shall be situated away from streets, swales, or other waterways and shall be seeded and/or mulched immediately.

4. Silt fence or other sediment barriers shall control sheet flow runoff from the building lot. These shall not be constructed in channels or areas of concentrated flow. Other sediment controls such as sediment traps and inlet protection shall also be used as needed to control sediment runoff. Sediment control practices shall be inspected weekly after storm events, and maintained in good working condition.

   Sediment control practices are described in Chapter 6 along with their limitations. Sediment Controls should be appropriate to the amount and type of flow (sheet flow or concentrated) received, and their timing of installation. Sediment barriers such as silt fence or filter berms are most common, but more substantial controls such as sediment traps may be needed due to the size of the contributing drainage area or the need for a lower maintenance. Note that sediment barriers must be situated downstream of the work area, on the contour and perpendicular to the flow direction to be most effective. To increase the effectiveness of sediment controls, leave as much area as possible in vegetation. Besides limiting erosion, these areas slow runoff and increase the settling of soil particles in runoff.

   Inlet protection devices used on curb and yard inlets may not be considered sufficient if storm sewers and catch basins are not be completely installed prior to construction on the lot or if inlet protection devices are the only practice capturing sediment. Inlet protection may be sufficient, if the storm sewer system subsequently drains to a sediment pond or if additional sediment controls are placed upstream of the inlet on the lot.

5. Construction vehicle access shall be limited to one route, to the greatest extent practical. The access shall be gravel or crushed rock underlain with geotextile, typically applied to the driveway area. This provides a single access point for construction personnel, equipment and the delivery of materials in order to prevent tracking of mud onto streets and to maintain the integrity of other sediment controls on the lot. Further information and details regarding construction site entrances are available in Chapter 7.

6. Mud tracked onto streets or sediment settled around curb inlet protection shall be removed daily or as needed to prevent it from accumulating. It shall be removed by shoveling and scraping and shall NOT be washed off paved surfaces or into storm drains. Sediment cleaned from streets and control practices shall be placed where it will not be subject to erosion or concentrated runoff such as a level well-vegetated area where it is subsequently seeded.

Table 8.2.2 A Construction Sequence for Small Construction Sites

Stage	Actions	Dates
Mark off set aside areas	1. Fence naturally vegetated areas and the dripline of trees that will be maintained and protected during construction.	
Install initial sediment and erosion controls	2. Install appropriate sediment controls to protect down-stream and adjacent areas. These are to be installed prior to grading and construction begins and includes practices such as sediment traps, sediment barriers(silt fence, filter socks and berms) and protection of catch basins with inlet protection.	
	3. Install stone construction entrance prior to general grading or excavation or delivery of materials.	
Prepare site and construct improvements	4. Remove topsoil and stockpile, seeding stockpile immediately upon completion. Install sediment controls as necessary.	
	5. Grade site or excavate building foundation or basement.	
	6. Temporary seed rough graded areas and maintain or repair sediment controls as needed. Maintenance includes the removal of sediment from streets and sediment controls.	
	7. Construct the building and site improvements.	
Final grading and stabilization	8. Complete land grading and shaping. Soils shall be roughly graded, followed by the spreading and grading of topsoil. Installation of roof drains and other drains to stable outlets should be completed at this time.	
	9. Establish permanent vegetation. After reaching final grade elevations and leveling of topsoil, bare soils shall be stabilized with seed and mulch, sod or other permanent landscaping materials.	
	10. Remove temporary sediment control practices once vegetation is established.	

Specifications
for

Small Construction Site Controls

1. Preexisting vegetation shall be retained on idle portions of the building lot for as long as construction operations allow. Clearing shall be done so only active working areas are bare.

2. Temporary seed and/or mulch shall be applied to areas, such as stockpiles and rough graded areas, that are bare and not actively being worked. This shall apply to areas that will not be reworked for 21 days or more.

3. Stockpiles created from basement excavation and grading shall be situated away from streets, swales, or other waterways and shall be seeded and/or mulched immediately.

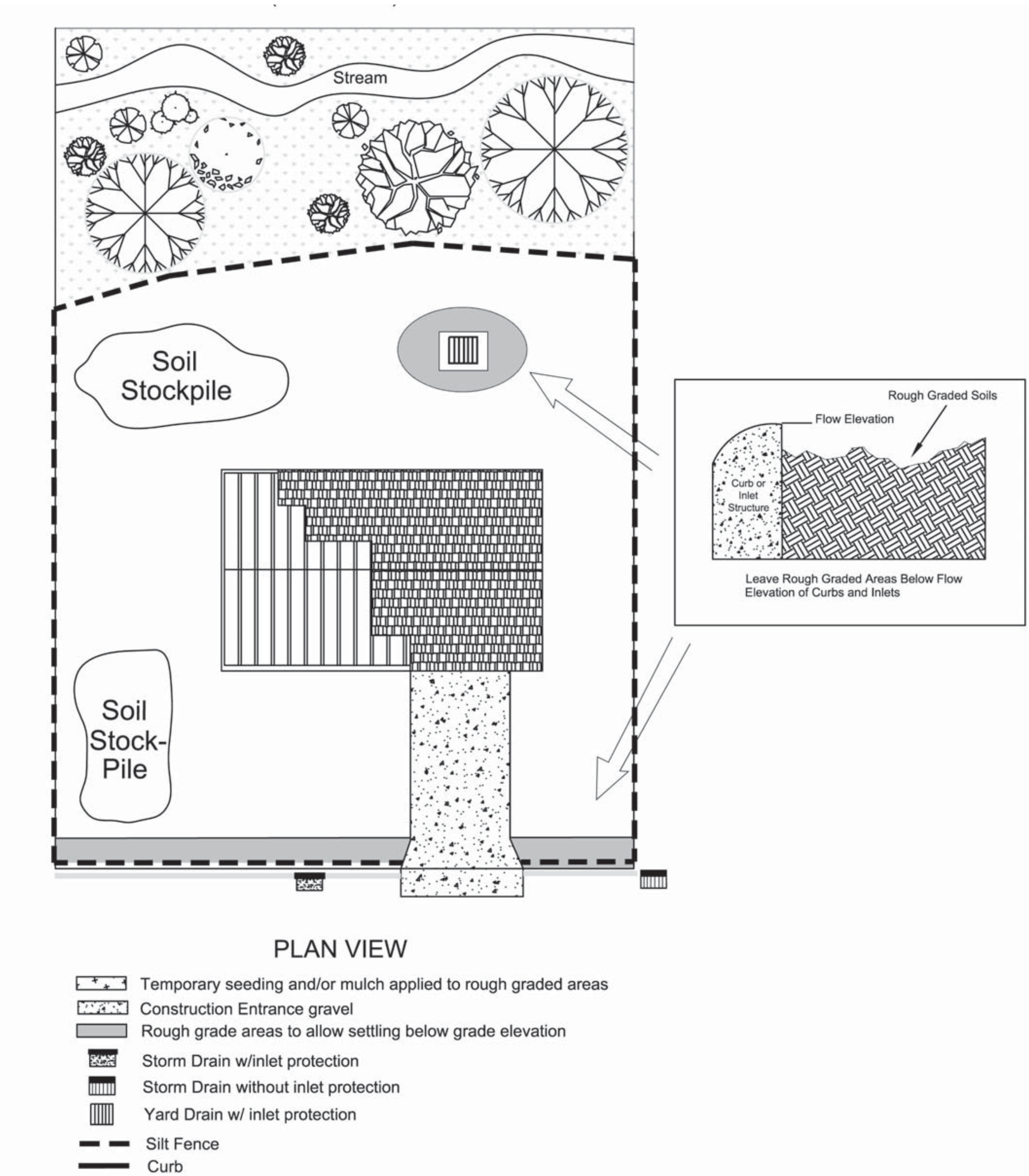
4. Silt fence or other sediment barriers shall control sheet flow runoff from the building lot. These shall not be constructed in channels or areas of concentrated flow. Other sediment controls such as sediment traps and inlet protection shall also be used as needed to control sediment runoff. Sediment control practices shall be inspected weekly after storm events, and maintained in good working condition.

5. Construction vehicle access shall be limited to one route, to the greatest extent practical. The access shall be gravel or crushed rock underlain with geotextile.

6. Mud tracked onto streets or sediment settled around curb inlet protection shall be removed daily or as needed to prevent it from accumulating. It shall be removed by shoveling and scraping and shall NOT be washed off paved surfaces or into storm drains. Sediment removed shall be placed where it will not be subject to erosion or concentrated runoff.

Specifications
for

Small Construction Site Controls



Appendix 1: Post-Construction Stormwater Design Examples

This appendix uses three hypothetical development sites in order to demonstrate the design of post-construction stormwater practices presented earlier in specifications.

Each practice example utilizes the existing and the proposed developed site and hydrologic characteristics to determine the sizing and configuration of each practice. The base requirements are presumed to be Ohio EPA's Construction General Permit post-construction requirements (detention of the water quality volume) and the detention of the critical storm (see the Critical Storm Method) from the development in order to prevent increases in downstream flooding and streambank erosion.

Each practice use the following steps to proceed through the design:

- Step 1 - Calculate Water Quality Volume (WQv)
- Step 2 - Compute Peak Discharge Requirements
- Step 3 - Identify Other Local Development Criteria/Requirements
- Step 4 - Determine if the Site and Soils Are Appropriate for the Practice
- Step 5 - Determine Practice Location and Preliminary Geometry to Meet Requirements
- Step 6 - Check Design to Ensure All Requirements Are Met

CONTENTS

Section A: Dry Extended Detention Basin

This design example illustrates the design of a dry extended detention stormwater basin that provides water quality treatment and peak discharge control within a highly impervious commercial development.

The layout of the North Country Automotive development is shown in Figure 1.A.1. The development site totals 7.7 acres draining to a single point on the north property line with no offsite watershed area. The site impervious area at completion of construction is estimated to be 5.3 acres. The example assumes that the local community has adopted the Critical Storm Method criteria to control peak discharges[1]. The pre-developed and post-developed site flow paths are shown in Figure 1.A.2. (limited to those used for calculations).

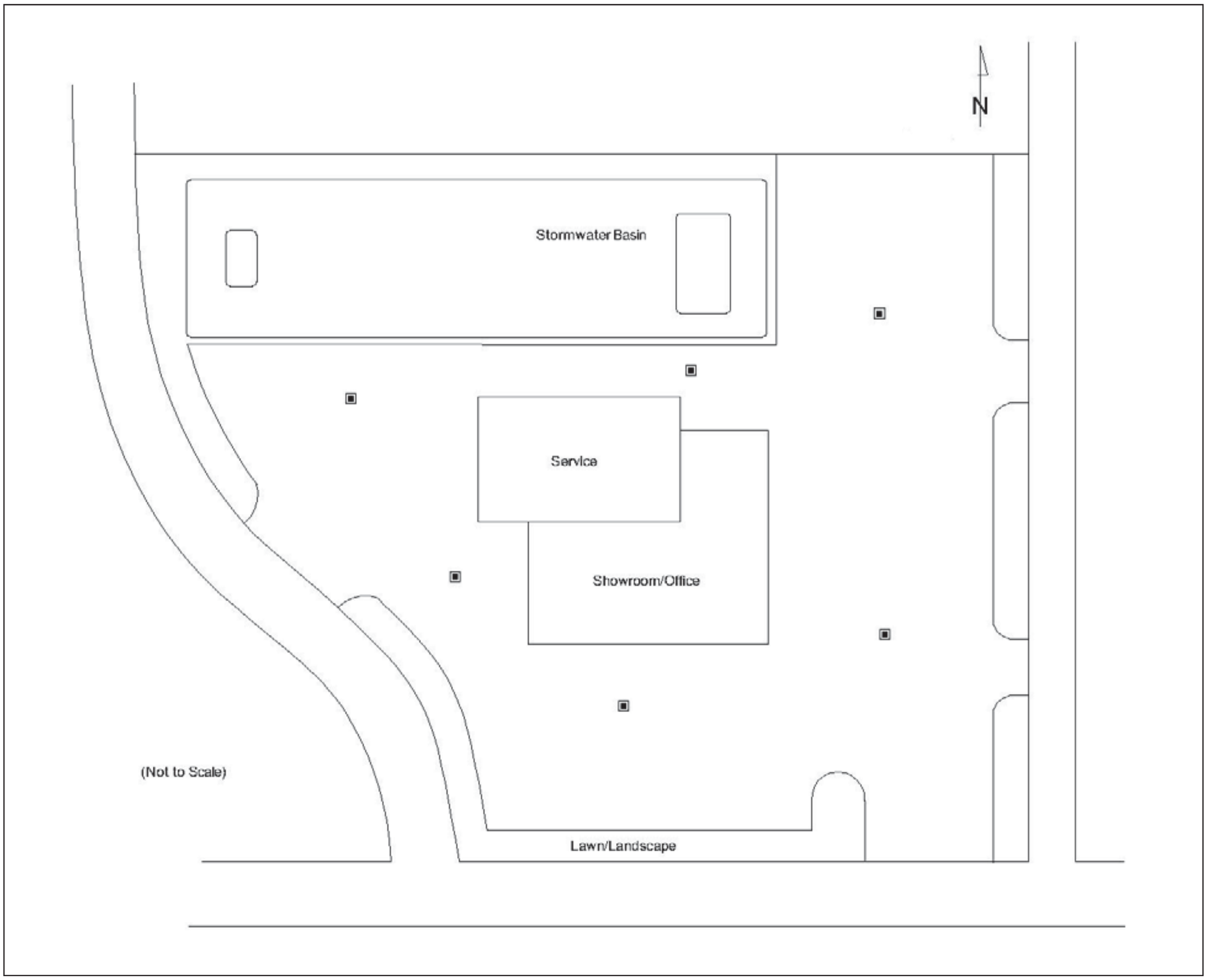


Figure 1.A.1. North Country Automotive Site Plan.

[1] The Critical Storm Method is a set of criteria for controlling the peak discharge of stormwater from large storm events (1 - 100 yr recurrence interval) recommended by ODNR-DSWC since 1980. See Goettemoeller, R.L., D.P. Hanselmann, and J.H. Bassett. 1980. Ohio Stormwater Control Guidebook. Ohio Department of Natural Resources, Division of Soil and Water Districts, p47.

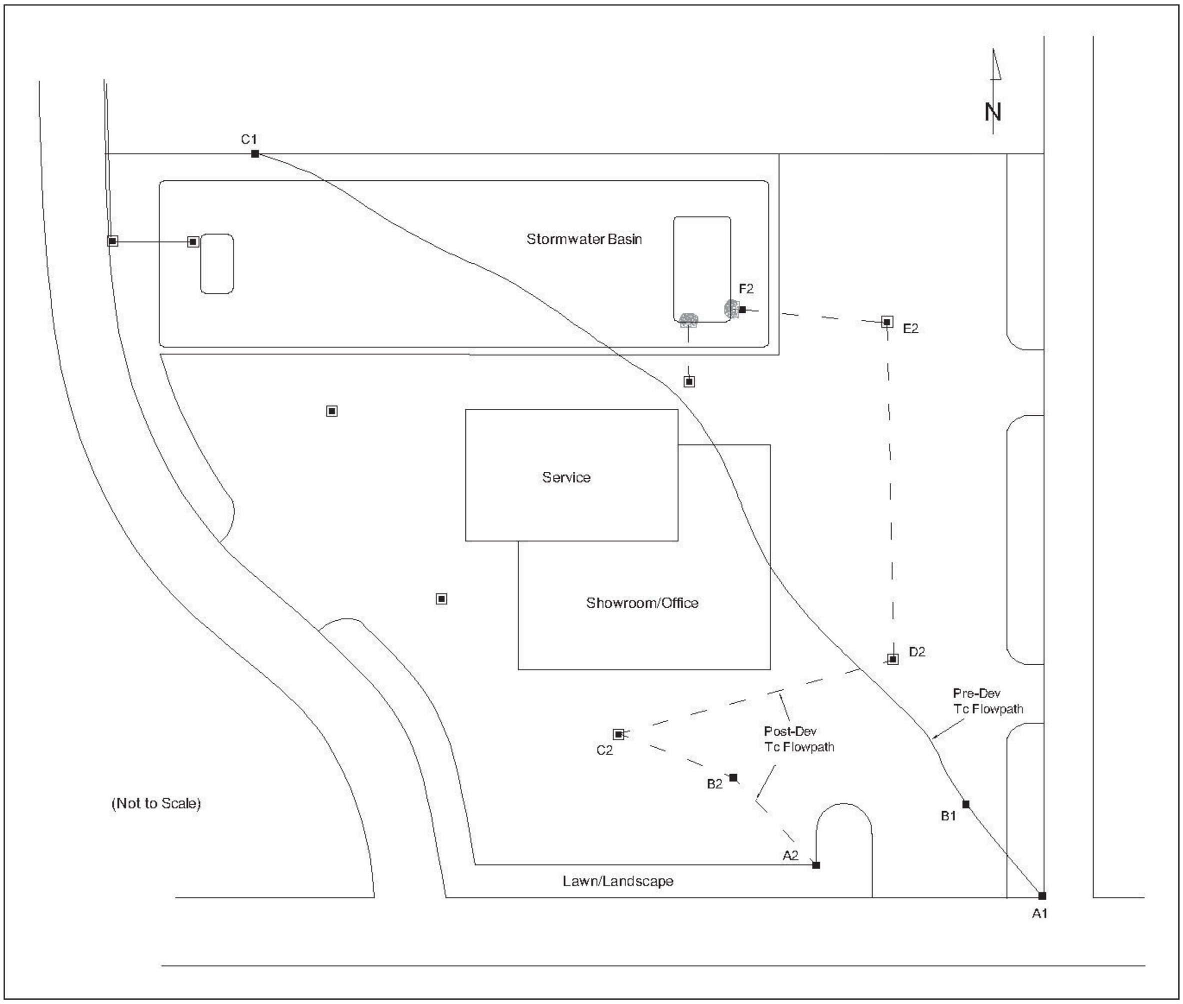


Figure 1.A.2. North Country Automotive Site Plan with pre-developed and post-developed flow paths.

Site Data
Total Drainage Area (A) = 7.7 ac
Estimated Impervious Area = 5.3 ac
Soil Types
Existing: 100% HSG-C
Proposed: 100% HSG-D

Summary Hydrologic Data
WQv = 0.26 ac-ft

	Pre	Post
CN =	70	96
Tc =	33.3 min	3.5 min

Calculation of Preliminary Stormwater Storage Volumes and Peak Discharges

Step 1 - Calculate Water Quality Volume (WQv)

The water quality volume (WQv) is a post-construction stormwater control requirement in Ohio (NPDES Storm Water Construction General Permit; OEPA, 2008). The WQv is determined according to the following equation:

$$WQv = C*P*A \qquad \text{Equation 1.A.1}$$

where:

C = runoff coefficient

P = 0.75 inch precipitation depth

A = drainage area

For open water, C = 1. At this site, the surface area of the detention basin at full WQv is estimated to be 0.4 acres.

For the remainder of the site, the runoff coefficient can either be selected from Table 1 of the NPDES Storm Water Permit, or calculated using the following equation:

$$C = 0.858i^3 - 0.78i^2 + 0.774i + 0.04 \qquad \text{Equation 1.A.2}$$

where i is the fraction of post-construction impervious surface.
For this site, total impervious area = 5.3 acres from a drainage area of 7.3 acres (i.e., total site drainage area - surface area of detention basin at full WQv).

$$i = 5.3/7.3 = 0.73 \qquad \text{Equation 1.A.3}$$

$$C = 0.858(0.73)^3 - 0.78(0.73)^2 + 0.774(0.73) + 0.04 = 0.52 \qquad \text{Equation 1.A.4}$$

Therefore, the WQv is:

$$WQv = [1.0*0.75\text{ in}*0.4\text{ ac} + 0.52*0.75\text{ in}*7.3\text{ ac}]*(1\text{ ft}/12\text{ in}) \qquad \text{Equation 1.A.5}$$

= <u>0.26 ac-ft</u>

= 11,400 ft^3

Peak Discharge Summary
Project: North Country Automotive

	Cover Description	Soil Name	Hydrologic Group	Drainage Y/N	CN	Area (acres)
Existing Condition	Woods (good condition)	Ellsworth	C		70	7.7
	Existing Conditions				**70**	**7.7**
	Cover Description	**Soil Name**	**Hydrologic Group**		**CN**	**Area (acres)**
Proposed Condition	Impervious Area				98	5.3
	Open space (good condition)	Ellsworth	D		80	0.8
	Detention Basin				98	1.6
	Proposed Conditions				**96**	**7.7**

Table 1.A.1. Curve Number (CN) for existing (pre-developed) and proposed (post-developed) condition.

	Segment	Flow Type	Surface Cover	Mannings n	Length ft	Slope %	Velocity ft/s	Tt min
Existing Condition	A_1 to B_1	Overland - sheet	Woods - Light Underbrush	0.40	100	3		21.0
	B_1 to C_1	Overland - shallow conc	Woods - Light Underbrush	0.10	700	3.5	0.95	12.3
	Total	**Existing**			**800**			**33.3**
	Segment	**Flow Type**	**Surface Cover**	**Mannings n**	**Length ft**	**Slope %**	**Velocity ft/s**	**Tt min**
Proposed Condition	A_2 to B_2	Overland - sheet	Pavement	0.011	100	2.0		1.4
	B_2 to C_2	Overland - shallow conc	Pavement	0.025	100	2.0	2.9	0.6
	C_2 to D_2	Pipe - storm drain (12")	Pipe	0.013	250	2.0	6.4	0.6
	D_2 to E_2	Pipe - storm drain (15")	Pipe	0.013	300	2.0	7.4	0.7
	E_2 to F_2	Pipe - storm drain (18")	Pipe	0.013	150	4.0	11.9	0.2
	Total	**Proposed**			**900**			**3.5**

Table 1.A..2. Time of Concentration (Tc) for existing ((pre-developed) and proposed (post-developed) condition.

RI years	P in	Q_{pre} in	Q_{post} in	Percent Increase Q	q_{pre} cfs	q_{post} cfs
1	2.00	0.24	1.57	554	0.86	21.3
2	2.40	0.41	1.96	378	1.8	26.1
5	2.98	0.70	2.53	261	3.7	33.1
10	3.47	0.99	3.02	205	5.5	39.0
25	4.17	1.44	3.71	158	8.5	47.3
50	4.76	1.86	4.29	131	11.2	54.3
100	5.38	2.32	4.91	112	14.1	61.6

Table 1.A.3. Summary runoff depth (Q) and peak discharge (q) for existing (pre-developed) and proposed (post-developed) conditions with critical storm (bold type).

Step 2 - Compute Peak Discharge Requirements

Note: Peak discharge control is typically regulated through local entities (e.g. stormwater district, municipal, township or county governments). The state of Ohio recommends use of the Critical Storm Method[1] for peak discharge control, but the requirements will vary by community. Check local stormwater regulations to determine which peak discharge control method you must use.

This example uses the NRCS Curve Number Methodology to perform hydrologic calculations. TR-20, HEC-HMS or other software that uses NRCS procedures should provide similar results.

Tables 1-1 and 1-2 summarize the inputs necessary to determine the curve number (CN) and time of concentration (Tc) for the existing (pre-development) and proposed (post-development) conditions. Table 1-3 summarizes the existing and proposed runoff depths and peak discharges for the 1-year, 24-hr through 100-year, 24-hr rainfall events.

The *critical storm* is determined from the percent increase in runoff volume from the 1-year, 24-hr storm for the proposed (post-developed) conditions when compared to the existing (pre-developed) conditions (Goettemoeller et al., 1980):

$$Percent\ Increase = \frac{Q_{post} - Q_{pre}}{Q_{pre}} x\, 100 \qquad \text{Equation 1.A.6}$$

From Table 1-3, the percent increase in the 1-year, 24-hr runoff for the proposed development is:

$$Percent\ Increase = \frac{1.57 - 0.24}{0.24} x\ \ 100 = 554\% \qquad \text{Equation 1.A.7}$$

For an increase greater than 500%, the *critical storm* for peak discharge control is the 100-year, 24-hr event - i.e., the 100-year, 24-hr post-developed peak discharge must be less than the existing (pre-developed) 1-year, 24-hr peak discharge. These values are shown in bold type in Table 1.A.3.

Step 3 - Identify Other Local Development Criteria/Requirements

Commercial development in this community is subject to a 5% minimum landscaped area requirement - the proposed design meets this requirement. No additional setback or stormwater requirements were identified.

Step 4 - Determine if the Development Site and Soils Are Appropriate for the Use of a Dry Extended Detention Basin

The site drainage area is 7.7 acres, all of which is mapped as Ellsworth silt loam soil in the county soil survey. Ellsworth silt loam soils are suitable for creation of an extended detention basin with a wet forebay and permanent micropool. The subsoil is silty clay loam derived from glacial till and has slow permeability. Because the soil has slow permeability, there may be extended periods when the basin cannot be mowed. This subsoil is suitable material for construction of the embankment for the stormwater basin.

[1] The Critical Storm Method is a set of criteria for controlling the peak discharge of stormwater from large storm events (1 - 100 yr recurrence interval) recommended by ODNR-DSWC since 1980. See Goettemoeller, R.L., D.P. Hanselmann, and J.H. Bassett. 1980. Ohio Stormwater Control Guidebook. Ohio Department of Natural Resources, Division of Soil and Water Districts, p47.

Step 5 - Determine Pond Location and Develop Preliminary Geometry to Meet WQv and Peak Discharge Requirements

The proposed location of the stormwater basin (see Figure 1.A.2) reflects the best combination of characteristics (landscape position, access to outlet, minimized earth moving, appropriate soils, etc.) for siting the basin. Existing ground elevation at the proposed pond outlet is 935 MSL. An existing 24" storm sewer runs along the west edge of the property, with an invert elevation of 928 MSL at the proposed discharge point. [For more information on siting and planning an extended detention basin, see section 2.6.]

The basin will be designed to include a permanent micropool and wet forebay, an extended detention volume to protect water quality and stream channel stability, and storage necessary to control the peak discharge rate.

The NPDES Storm Water Permit (OEPA, 2008) specifies a dry extended detention basin include a water quality volume (WQv) with a drawdown time of 48 hours. The permit also requires an additional sediment storage volume equal to 20% of the WQv which, for a dry extended detention basin, should consist of a permanent micropool and forebay each sized at 10% of the WQv.

$$V_{micropool} \text{ and } V_{forebay} \geq 0.1*WQv = 0.1*0.26 \text{ ac-ft} = 0.026 \text{ ac-ft} = 1140 \text{ ft}^3 \qquad \text{Equation 1.A.8}$$

A plan view of the basin layout (Figure 1.A.3) reflects the following:

- extended detention water quality volume (WQv)
- a wet forebay with a minimum volume of 0.1*WQv and 3' depth
- permanent micropool with a minimum volume of 0.1*WQv and 4' depth
- a flow length to flow width ratio of 4:1, exceeding the 3:1 requirement
- positive slope (~0.8%) toward the outlet to facilitate surface drainage [Note: this is not enough slope to prevent extended periods of soil wetness.]
- 4:1 side slopes for safety and ease of maintenance
- an emergency spillway constructed in native soil (i.e., not in the constructed embankment)

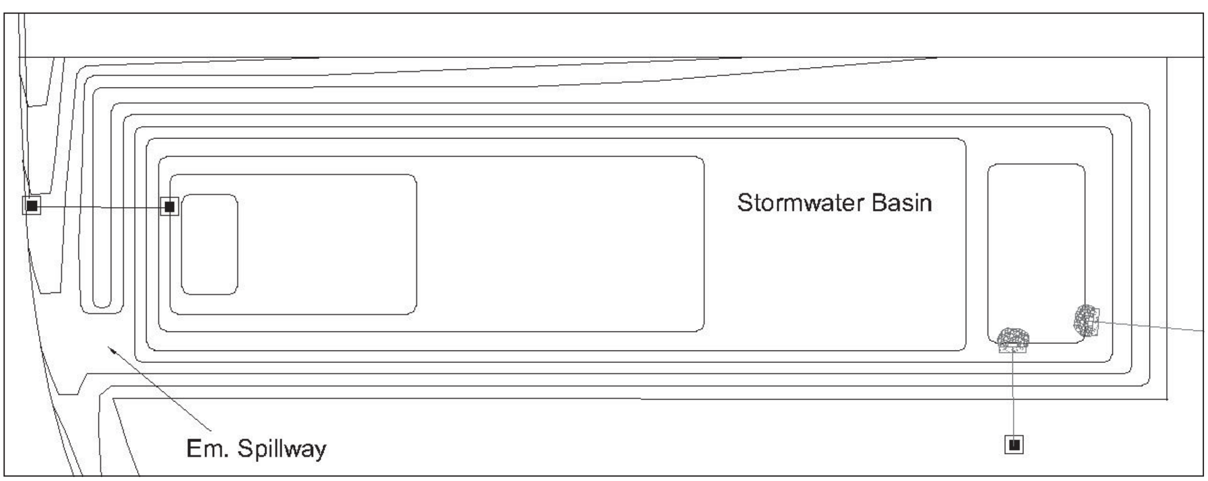


Figure 1.A.3. Plan View of the Basin Layout.

Set elevations for pond structures

- The pond bottom is set at elevation 930.0 and the riser invert is set at 929
- A manhole will be installed in the sewer main with a barrel invert (outfall) elevation at 928 ft

Establish permanent micropool and WQv water surface elevations

A stage-area-storage table (Table 1.A.4) reflects the geometry of the stormwater basin (Figure 1.A.3) designed to meet permanent micropool, forebay, extended detention (WQv) and peak discharge control requirements.

- The permanent micropool volume of 0.05 ac-ft (surface elevation 934.0) exceeds 0.1*WQv
- The extended detention water quality volume WQv of 0.26 ac-ft above the permanent micropool has a top elevation of approximately 935.5

Elevation MSL (ft)	Surface Area (acre)	Average Area (acre)	Incremental Depth (ft)	Incremental Volume (ac-ft)	Cumulative Volume (ac-ft)	Vol above Perm Pool (ac-ft)
930.0	0.004	-	-	-	-	-
934.0	0.02	0.01	4.0	0.05	0.05	-
934.5	0.10	0.06	0.5	0.03	0.08	0.03
935.0	0.22	0.16	0.5	0.08	0.16	0.11
935.5	0.40	0.31	0.5	0.15	0.31	0.26
936.0	0.52	0.39	0.5	0.20	0.48	0.43
937.0	1.05	0.76	1.0	0.76	1.24	1.19
938.0	1.25	1.15	1.0	1.15	2.39	2.34
939.0	1.36	1.30	1.0	1.30	3.69	3.64
940.0	1.47	1.41	1.0	1.41	5.10	5.05
941.0	1.58	1.53	1.0	1.53	6.63	6.58

Table 1.A.4. Stage-Area-Storage Information for Dry Extended Detention Basin.

Determine orifice size for 48-hour drawdown of WQv

The controlling parameters are WQv = 0.26 ac-ft, depth of WQv = 1.5 ft, and minimum drain time, T_d = 48 hours. Note that "the outlet structure for the post-construction BMP must not discharge more than the first half of the WQv in less than one-third of the drain time" (p22, NPDES Storm Water Construction General Permit; OEPA, 2008).

The average discharge rate for the WQv is:

$$Q_{avg} = \frac{WQv}{T_d} = \frac{(0.26\ ac \cdot ft)\left(\frac{43560\ ft^2}{1\ ac}\right)}{(48\ hr)\left(3600\ \frac{s}{hr}\right)} = 0.065\ cfs$$ Equation 1.A.9

The discharge equation for an orifice is:

$$Q = ca\sqrt{2gh}$$ Equation 1.A.10

By rearranging, we can estimate needed orifice area, as:

$$a = \frac{Q}{c\sqrt{2gh}}$$ Equation 1.A.11

Using an orifice coefficient of c = 0.6, and average head, h = d/2 = (1.5 ft)/2 = 0.75 ft, the required orifice size is:

$$a = \frac{0.065\ \frac{ft^3}{s}}{0.6\sqrt{2(32.2\ \frac{ft}{s^2})(0.75\ ft)}} = 0.0156\ \ ft^2$$ Equation 1.A.12

resulting in an estimated orifice diameter of:

$$d = \left(\frac{4a}{3.14}\right)^{0.5} = \left[\frac{4(0.0156\,ft^2)}{3.14}\right]^{0.5} = 0.141\,ft \times \frac{12\,in}{1\ ft} = 1.7\,in$$ Equation 1.A.13

This estimate is a good starting point for selecting the WQv orifice size, because it will always meet the two drawdown requirements: (1) the specified minimum drain time, T_d; and (2) the outlet must not discharge more than the first half of the WQv (or EDv) in less than one-third of the drain time. A larger or smaller orifice should be considered if it will help meet other environmental, cost, or maintenance goals, but must be tested for the two drawdown criteria.

Choosing the largest orifice size meeting the criteria lowers the likelihood of a clogged orifice and slightly lessens the storage volume required to meet the peak discharge requirement. In this situation, a 1.7" diameter orifice was the largest orifice that met the above two drawdown requirements (see Figure 1.A.4) and, thus, will be used as the extended detention (WQv) outlet.

Determine storage and outlet configuration to meet peak discharge requirements

As noted under Step 2, this dry detention basin is designed to meet the Critical Storm Method (CSM) for peak discharge control as well as the WQv requirement. Additional storage volume must be added that, with appropriate outlet design, will allow the basin to meet the following requirement:

- The peak rate of discharge from the post-construction 100-year, 24-hour event (the critical storm) must be released at the existing (pre-development) 1-year, 24-hour discharge rate

Proprietary stormwater modeling software was used to try a combination of stage-storage and outlet configurations until the critical storm requirement was satisfied while considering the following:

- use best practices outlined in Section 2.6 of the Rainwater and Land Development manual
- minimize cut/fill and grading

The resulting detention basin geometry is presented in Figure 1.A.3 and Table 1.A.4. The resulting outlet configuration is shown in Figure 1.A.5.

The outlet structure consists of a 3 ft by 3 ft concrete catch basin (e.g., ODOT No. 2-3) with invert at 929 MSL and 2.5'x2.5' iron grate at 938.1 MSL. The following comprise the outlets:

- 1.7" diameter extended detention water quality volume (WQv) orifice (invert 934.0 MSL) drilled into 6" PVC pipe using a non-clogging design
- 4.2" diameter orifice (invert 935.5 MSL) that controls release of the critical storm (100-year, 24-hour)
- 2.5'x2.5' iron grate (invert 938.1 MSL) for emergency overflow and maintenance access

The catch basin will be connected - using a 12" diameter conduit - to the 2' diameter storm sewer at the road along the west property boundary. A tailwater analysis was performed using the modeling software and the storm sewer's design elevation (invert at 928 MSL; 25-yr full pipe flow at 930 MSL) and assumed elevation for the 100-yr event (935 MSL).

In addition, this design includes an emergency spillway excavated into native soil with the following characteristics:

- Invert (crest) elevation of 938.5 MSL
- Level section length of 25 ft, weir length (i.e., crest width) of 25 ft
- Spillway crest perpendicular to flow
- With all other outlets blocked and starting from the permanent pool elevation of 934.0 MSL, will safely convey the 100-yr, 24-hr event with at least 1 ft freeboard below top of embankment

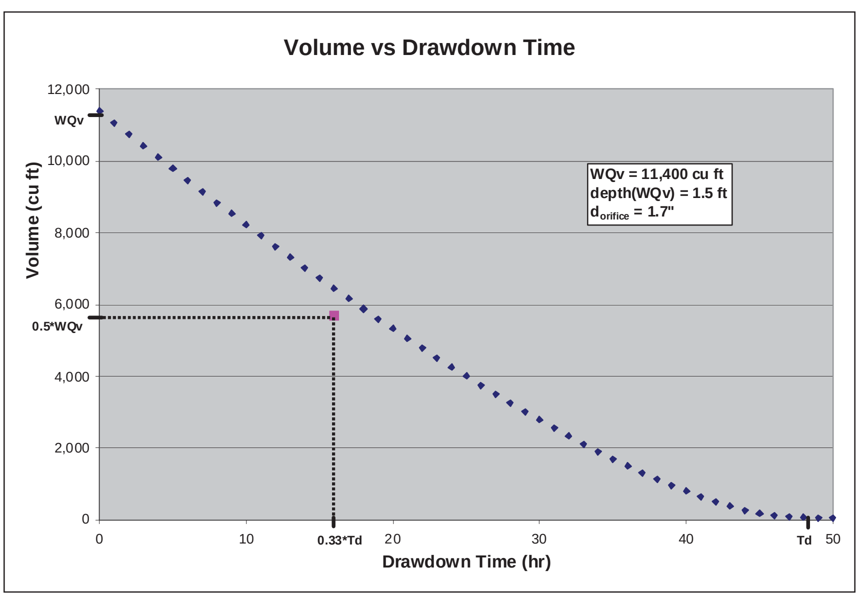


Figure 1.A.4. Dry Extended Detention Basin - Drawdown from Full WQv.

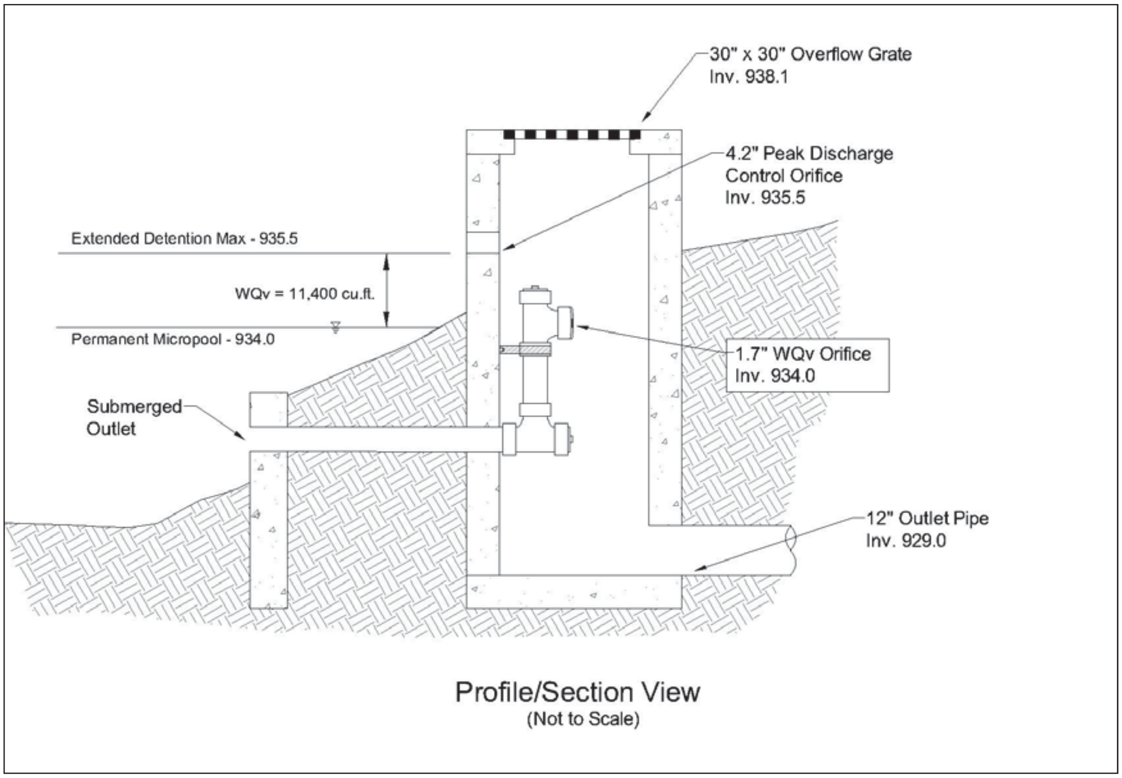


Figure 1.A.5. Outlet Configuration for Dry Extended Detention Basin (not to scale).

Step 6 - Check Design to Ensure All Requirements Are Met

From full WQv, check that WQv meets minimum 48 hour drain time, and discharges no more than 1/2 the water quality volume, 0.5*WQv (5050 ft^3), in the first 1/3 of the drain time, 0.33*T_d (16 hr). This requirement is met and illustrated in Figure 1.A.4.

Check peak discharge for all events (see Table 1.A.5).

RI years	P in	$q_{post-in}$ cfs	Allowed $q_{post-out}$ cfs	Estimated $q_{post-out}$ cfs
1	2.00	21.3	0.86	0.48
2	2.40	26.1	0.86	0.55
5	2.98	33.1	0.86	0.63
10	3.47	39.0	0.86	0.68
25	4.17	47.3	0.86	0.75
50	4.76	54.3	0.86	0.80
100	5.38	61.6	0.86	0.85

Table 1.A.5. Critical Storm Method Peak Discharge Check.

Section B: Wet Extended Detention Basin

This design example illustrates the design of a wet extended detention stormwater basin that provides water quality treatment and peak discharge control within a condominium development. This residential development will consist of 74 units of "active senior" living units and a well-equipped clubhouse for recreation, exercise and social functions. The layout of the development is shown in figure 1.B.1.

The development site consists of 24.2 acres having 10.2 acres of impervious area. An additional 8.5 acres of off-site area drains to the development site. The pre-developed site soils and flow paths are shown in Figure 1.B.2, while the post-developed flow paths (limited to that used for calculations) are shown in figure 1.B.3.

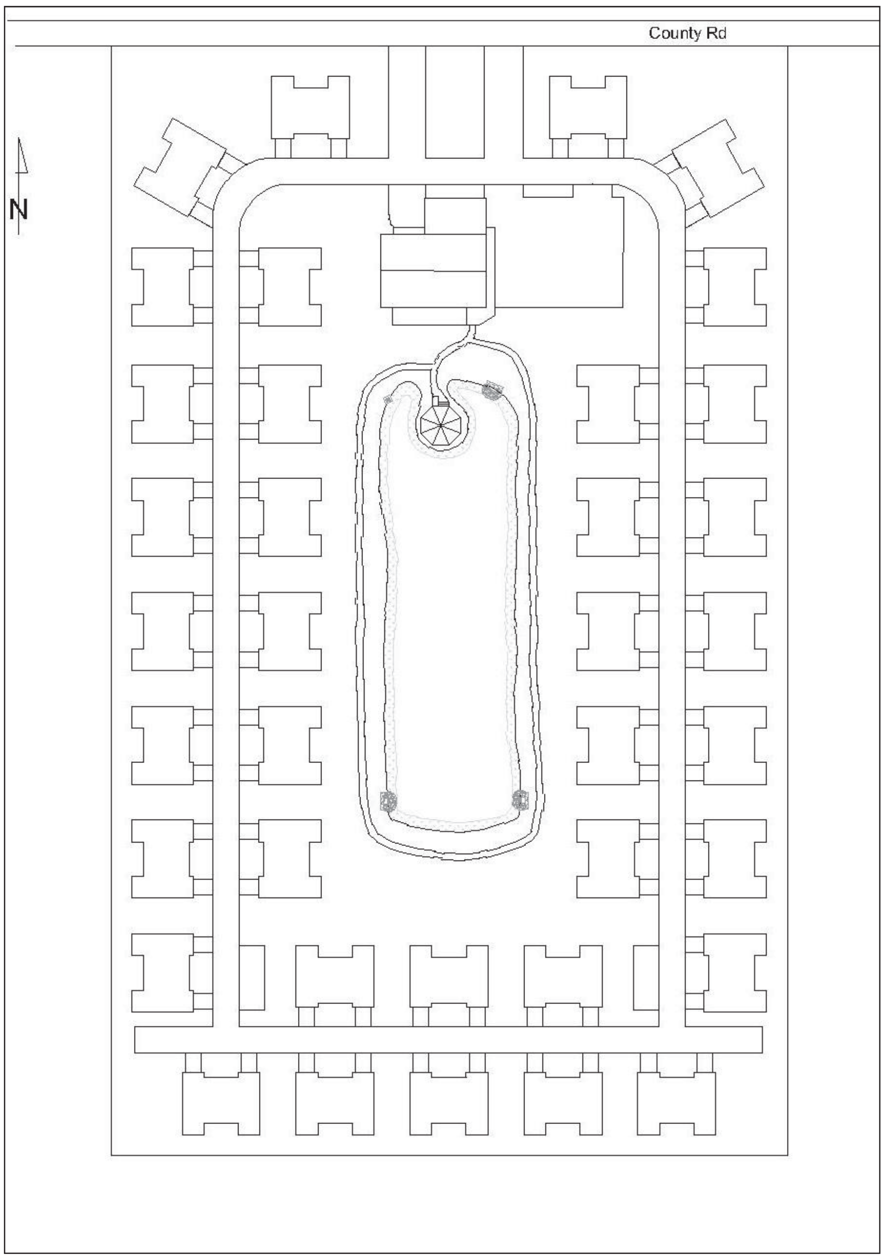


Figure 1.B.1. Autumn Knoll Subdivision Site Plan.

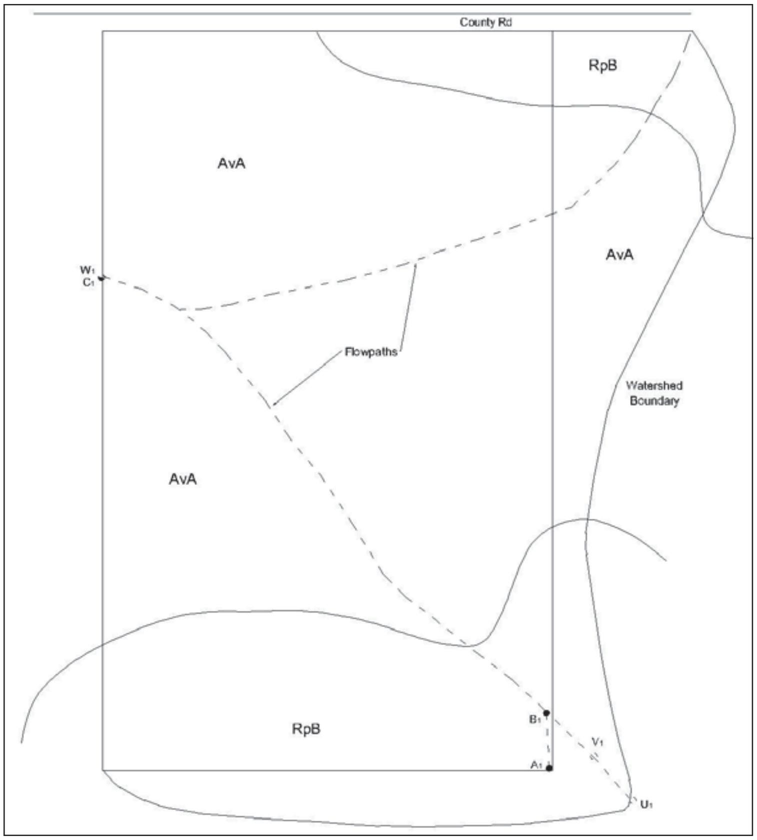


Figure 1.B.2. Pre-Development On-site and Off-site Soils and Drainage.

<u>Development Site Data</u>
Total On-Site Drainage Area (A) = 24.2 ac
Estimated Impervious Area = 10.2 ac
Soil Types
Existing: 25% HSG-C, 75% HSG-D
Proposed: 100% HSG-D

<u>Drainage from Off-site</u>
Off-site Drainage Area (A) = 8.5 ac
Estimated Impervious Area = 0 ac
Soil Types: 60% HSG-C, 40% HSG-D

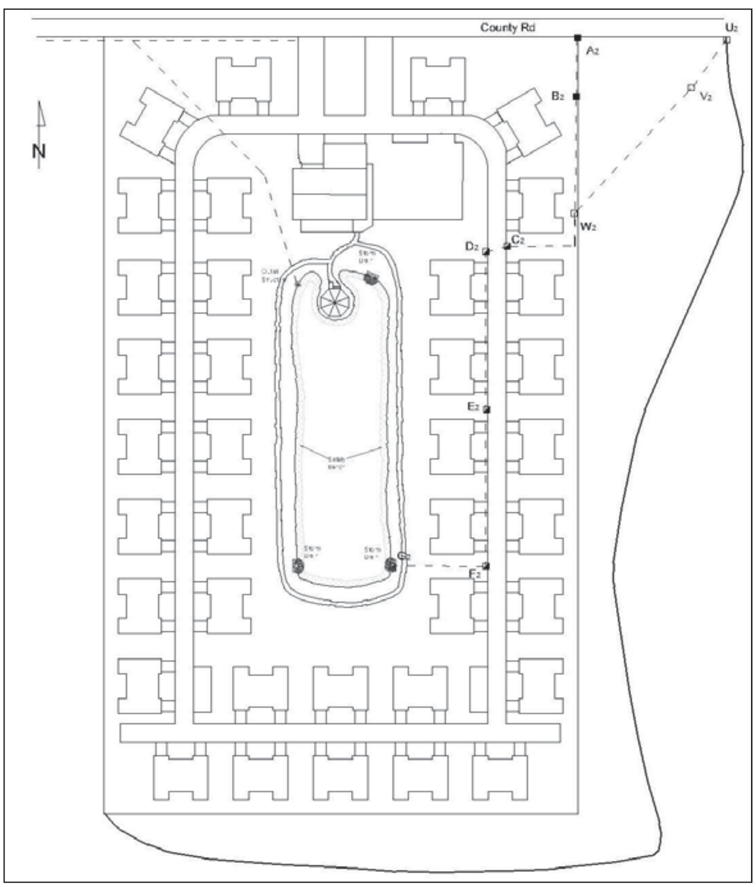


Figure 1.B.3. Post-Development On-site and Off-site Drainage.

<u>Summary Hydrologic Data</u>
WQv = 0.53 ac-ft
EDv = 0.40 ac-ft

	Pre	Post
CN(site) =	84	89
Tc(site) =	66 min	27 min
CN(offsite) =	83	83
Tc(offsite) =	71 min	30 min

Calculation of Preliminary Stormwater Storage Volumes and Peak Discharges

Step 1 - Calculate Water Quality Volume (WQv)

The water quality volume (WQv) is a post-construction stormwater control requirement in Ohio (NPDES Storm Water Construction General Permit; OEPA, 2008). The WQv is determined according to the following equation:

$$WQv = C*P*A \qquad \text{Equation 1.B.1}$$

where:

C = runoff coefficient

P = 0.75 inch precipitation depth

A = drainage area

For open water, C = 1. At this site, the surface area of the detention basin at full extended detention volume is estimated to be 1.5 acres.

For the remainder of the site, the runoff coefficient can either be selected from Table 1 of the NPDES Storm Water Permit, or calculated using the following equation:

$$C = 0.858i^3 - 0.78i^2 + 0.774i + 0.04 \qquad \text{Equation 1.B.2}$$

where i is the fraction of post-construction impervious surface.

For this site, total impervious area = 10.2 acres from a drainage area of 22.7 acres (i.e., total site drainage area - surface area of detention basin).

$$i = 10.2/22.7 = 0.45 \qquad \text{Equation 1.B.3}$$

$$C = 0.858(0.45)^3 - 0.78(0.45)^2 + 0.774(0.45) + 0.04 = 0.31 \qquad \text{Equation 1.B.4}$$

Therefore, the WQv is:

$$WQv = [1.0*0.75 \text{ in}*1.5 \text{ ac} + 0.31*0.75 \text{ in}*22.7 \text{ ac}]*(1 \text{ ft}/12 \text{ in}) \qquad \text{Equation 1.B.5}$$

$$= \underline{0.53 \text{ ac-ft}}$$

$$= 23{,}200 \text{ ft}^3$$

Step 2 - Compute Peak Discharge Requirements

> Note: Peak discharge control is typically regulated through local entities (e.g. stormwater district, municipal, township or county governments). The state of Ohio recommends use of the Critical Storm Method[1] for peak discharge control, but the requirements will vary by community. Check local stormwater regulations to determine which peak discharge control method you must use.

This example uses the NRCS Curve Number Methodology to perform hydrologic calculations. TR-20, HEC-HMS or other software that uses NRCS procedures should provide similar results.

Tables 1.B.1 and 1.B.2 (a and b) summarize the inputs necessary to determine the curve number (CN) and time of concentration (Tc) for the existing (pre-development) and proposed (post-development) conditions. Table 1.B.3 summarizes the existing and proposed runoff depths and peak discharges for the 1-year, 24-hr through 100-year, 24-hr rainfall events.

The *critical storm* is determined from the percent increase in runoff volume generated from the development site for the 1-year, 24-hr storm, comparing proposed (post-developed) conditions to the existing (pre-developed) conditions (Goettemoeller et al., 1980):

$$Percent\ \ Increase = \frac{Q_{post} - Q_{pre}}{Q_{pre}} x\, 100 \qquad \text{Equation 1.B.6}$$

Using data from Table 1.B.3, the percent increase in the 1-year, 24-hr runoff volume for the proposed development site is:

$$Percent\ \ \ Increase\ \ = \frac{1.38 - 1.05}{1.05} x\ \ 100\ = 31\,\% \qquad \text{Equation 1.B.7}$$

For an increase greater than 20% but less than 50%, the *critical storm* for peak discharge control is the 5-year, 24-hr event - i.e., the stormwater detention facility must be designed such that the 5-year, 24-hr post-developed peak discharge does not exceed the existing (pre-developed) 1-year, 24-hr peak discharge. These values are shown in bold type in Table 1.B.3. In addition, the proposed peak discharge for the 10-year through 100-year events must not exceed the existing (pre-developed) discharge for like year events.

Step 3 - Identify Other Local Development Criteria/Requirements

The local subdivision regulations included lot size, lot width, road width and setback requirements that affected site layout. No additional stormwater requirements were identified.

Step 4 - Determine if the Development Site and Soils Are Appropriate for the Use of a Wet Extended Detention Basin

The site drainage area is 24.2 acres, all of which is mapped as Rossmoyne silt loam or Avonburg silt loam soil in the county soil survey[2]. The wet basin will be located in area mapped solely as Avonburg silt loam. Avonburg silt loam soils are suitable for creation of an extended detention basin with a permanent pool. The subsoil is clay loam derived from glacial till and has slow permeability. The constructed basin will lie predominantly below existing grade; a small amount of soil material will be used for construction of an embankment along the western and northern edges of the stormwater basin.

[1] The Critical Storm Method is a set of criteria for controlling the peak discharge of stormwater from large storm events (1 - 100 yr recurrence interval) recommended by ODNR-DSWC since 1980. See Goettemoeller, R.L., D.P. Hanselmann, and J.H. Bassett. 1980. Ohio Stormwater Control Guidebook. Ohio Department of Natural Resources, Division of Soil and Water Districts, p47.

[2] Note - Readily available county soil survey data provide excellent planning level information but typically are not accurate enough for engineering design. As part of site evaluation, a certified soil scientist should be contracted to perform an on-site soil investigation to provide an accurate representation of soil conditions and limitations at the development site.

Peak Discharge Summary
Project: Autumn Knoll Senior Living Residential Development

	Cover Description	Soil Name	Hydrologic Group	CN	Area (acres)
Existing Condition Site Only	Agriculture - Row Crop SR & CR	Rossmoyne	C	82	6.1
	Agriculture - Row Crop SR & CR	Avonburg	D	85	18.1
	Existing Conditions			**84**	**24.2**
	Cover Description	**Soil Name**	**Hydrologic Group**	**CN**	**Area (acres)**
Proposed Condition Site Only	Impervious Area			98	10.2
	Open space (good cond)	Rossmoyne/Avonburg	D	80	12.0
	Detention Basin			98	2.0
	Proposed Conditions			**89**	**24.2**
	Cover Description	**Soil Name**	**Hydrologic Group**	**CN**	**Area (acres)**
Off-site Condition	Agriculture - Row Crop SR & CR	Rossmoyne	C	82	5.1
	Agriculture - Row Crop SR & CR	Avonburg	D	85	3.4
	Existing Conditions			**83**	**8.5**

Table 1-B-1. Curve Number for existing and proposed conditions, as well as off-site area.

	Segment	Flow Type	Surface Cover	Mannings n	Length ft	Slope %	Veloctiy ft/s	Tt min
Existing Condition Site Only	A_1 to B_1	Overland - sheet	Cultivated Residue Cover >20%	0.17	100	1.2		14.0
	B_1 to C_1	Overland - shallow conc	Cultivated - Minimum Tillage	0.101	1130	0.5	0.4	52.3
	Total	**Existing**			**1230**			**66.3**
	Segment	**Flow Type**	**Surface Cover**	**Mannings n**	**Length ft**	**Slope %**	**Veloctiy ft/s**	**Tt min**
Proposed Condition Site Only	A_2 to B_2	Overland - sheet	Dense Grass	0.24	100	1.0		19.9
	B_2 to C_2	Overland - shallow conc	Grass Swale	0.050	380	1.0	1.6	3.9
	C_2 to D_2	Pipe - storm drain (18”)	Pipe	0.013	40	0.6	3.3	0.2
	D_2 to E_2	Pipe - storm drain (18”)	Pipe	0.013	260	0.3	3.3	1.3
	E_2 to F_2	Pipe - storm drain (24”)	Pipe	0.013	260	0.2	3.9	1.1
	F_2 to G_2	Pipe - storm drain (30”)	Pipe	0.013	170	0.3	4.6	0.7
	Total	**Proposed**			**910**			**27.0**

Table 1-B-2a. Time of Concentration (Tc) for existing and proposed conditions, as well as drainage from the off-site area.

Peak Discharge Summary (cont'd)
Project: Autumn Knoll Senior Living Residential Development

	Segment	Flow Type	Surface Cover	Mannings n	Length ft	Slope %	Veloctiy ft/s	Tt min
Existing Condition Off-site Condition	U_1 to V_1	Overland - sheet	Cultivated Residue Cover >20%	0.17	100	1.5		12.8
	V_1 to W_1	Overland - shallow conc	Cultivated - Minimum Tillage	0.101	1250	0.5	0.4	57.9
	Total	**Existing**			**1350**			**70.7**
Proposed Condition Off-site Condition	**Segment**	**Flow Type**	**Surface Cover**	**Mannings n**	**Length ft**	**Slope %**	**Veloctiy ft/s**	**Tt min**
	U_2 to V_2	Overland - sheet	Cultivated Residue Cover >20%	0.17	100	1.5		12.8
	V_2 to W_2	Overland - shallow conc	Cultivated - Minimum tillage	0.101	300	0.7	0.4	11.9
	W_2 to C_2	Overland - shallow conc	Grass Swale	0.050	180	1.0	1.6	1.9
	C_2 to D_2	Pipe - storm drain (18")	Pipe	0.013	40	0.3	3.3	0.2
	D_2 to E_2	Pipe - storm drain (18")	Pipe	0.013	260	0.3	3.3	1.3
	E_2 to F_2	Pipe - storm drain (24")	Pipe	0.013	260	0.3	3.9	1.1
	F_2 to G_2	Pipe - storm drain (30")	Pipe	0.013	170	0.3	4.6	0.6
	Total	**Proposed**			**1310**			**29.8**

Table 1-B-2b. Time of Concentration (Tc) for existing and proposed condition for off-site drainage only.

RI years	P in	Q_{pre} in	Q_{post} in	$Q_{off\text{-}site}$ in	Q_{pre} Ac-ft	Q_{post} Ac-ft	q_{pre} cfs	q_{post} cfs
1	2.42	1.05	1.38	1.00	2.8	3.5	16.1	38.1
2	2.90	1.43	1.81	1.37	3.9	4.6	22.4	50.4
5	3.56	1.99	2.41	1.91	5.4	6.2	31.4	67.7
10	4.07	2.43	2.89	2.35	6.6	7.5	38.6	81.3
25	4.77	3.06	3.55	2.97	8.3	9.3	48.6	100.0
50	5.32	3.56	4.08	3.47	9.6	10.7	56.6	114.7
100	5.89	4.09	4.63	3.99	11.1	12.2	65.0	130.0

Table 1-B-3. Summary runoff depth or volume (Q) and peak discharge (q) for existing (pre-developed) and proposed (post-

Step 5 - Determine Pond Location and Develop Preliminary Geometry to Meet WQv and Peak Discharge Requirements

The proposed location of the stormwater basin (see Figure 1.B.1) reflects several goals for this development project (including appropriate soils). In particular, the wet basin is considered the centerpiece of this development, with "waterfront condos" selling for a premium. The basin will also be over-excavated to provide fill material to raise the elevation of the condo structures. Existing ground elevation at the proposed pond outlet is 829 MSL. As part of this development, a storm sewer will be installed along the county road to convey site runoff to a receiving stream to the west. At the connection point, the storm sewer is 36" and has an invert elevation of 818.5 MSL. [For more information on siting and planning an extended detention basin, see section 2.6.]

The stormwater basin includes a permanent pool, an extended detention volume to protect water quality and stream channel stability, and storage necessary to control the peak discharge rate.

The NPDES Storm Water Permit (OEPA, 2008) specifies a wet extended detention basin must include both a permanent pool (designated PPv below) and an extended detention volume (EDv) equal to 75% of the water quality volume (WQv), with an EDv drawdown time of 24 hours. The permit also requires that the permanent pool contain an additional sediment storage volume equal to 20% of the WQv.

EDv = 0.75* WQv = 0.75*0.53 ac-ft = 0.40 ac-ft = 17,400 ft^3 Equation 1-B-8

PPv $\geq$ (0.75 + 0.2)*WQv = 0.95*0.53 ac-ft = 0.50 ac-ft = 22,000 ft^3 Equation 1-B-9

A plan view of the basin layout (Figure 1-B-4) reflects the following:

- extended detention volume equal to 0.75*WQv
- permanent pool with a minimum volume of (0.75+0.2)*WQv and 6 foot minimum depth
- 4:1 sideslopes for safety and ease of maintenance
- shallow, submerged wetland safety benches around the perimeter
- an emergency spillway constructed in native soil
- 3 storm drain outlets draining subareas within the development site (note: the length to width ratio for each of the two drains at the far end of the basin (draining approximately 90% of the site) exceeds 3:1, whereas the storm drain for the clubhouse/parking lot (drains approximately 10% of the site) was located on the other side of the gazebo peninsula to extend flow pathway to minimize short-cutting.

<u>Set elevations for pond structures</u>

- The pond bottom and riser invert are set at elevation 820 MSL
- A pond drain will be included to facilitate drawdown for maintenance or repairs.

<u>Establish permanent pool and WQv water surface elevations</u>

A stage-area-storage table (Table 1.B.4) reflects the geometry of the stormwater basin (Figure 1.B.4) designed to meet permanent pool, extended detention (EDv) and peak discharge control requirements.

- The permanent pool volume (PPv) of 4.5 ac-ft (surface elevation 826.0) exceeds 0.95*WQv
- The extended detention volume (EDv) of 0.40 ac-ft above the permanent pool has a top elevation of approximately 826.26.

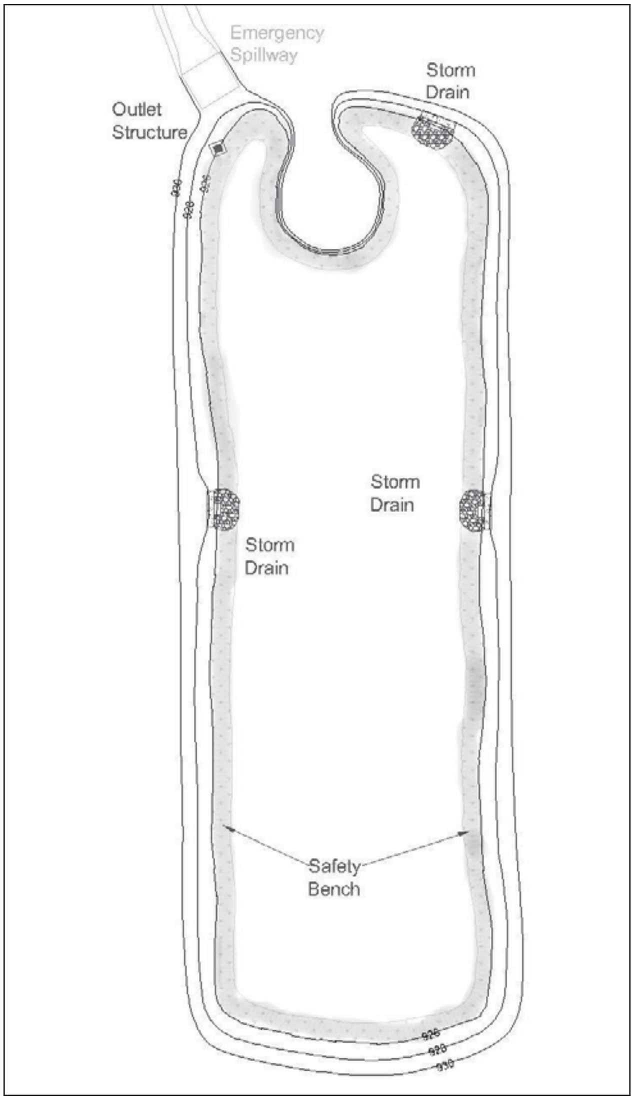


Figure 1.B.4. Preliminary Plan View of Wet Extended Detention Basin (not to scale).

Elevation MSL (ft)	Surface Area (acre)	Average Area (acre)	Incremental Depth (ft)	Incremental Volume (ac-ft)	Cumulative Volume (ac-ft)	Vol above Perm Pool (ac-ft)
820.0	0.004	-	-	-	-	-
826.0	1.50	0.75	6.0	4.5	4.5	-
826.3	1.53	1.51	0.3	0.4	4.9	0.4
827.0	1.61	1.57	0.7	1.2	6.1	1.6
828.0	1.72	1.66	1.0	1.7	7.8	3.3
829.0	1.83	1.78	1.0	1.8	9.6	5.1
830.0	1.98	1.90	1.0	1.9	11.5	7.0
831.0	2.20	2.09	1.0	2.1	13.6	9.1

Table 1.B.4. Stage-Area-Storage Information for Wet Extended Detention Basin.

Determine outlet geometry for 24-hour drawdown of EDv

The controlling parameters are EDv = 0.40 ac-ft, depth of EDv = 0.26 ft, and minimum drain time, T_d = 24 hours. Note that "the outlet structure for the post-construction BMP must not discharge more than the first half of the WQv in less than one-third of the drain time" (p22, NPDES Storm Water Construction General Permit; OEPA, 2008). This same criterion applies to the EDv.

When a wet detention basin has a large surface area (and thus the EDv depth is small), the designer has a wide variety of outlet options that will meet the two criteria above[3]. In this situation, combining a v-notch weir ("V" depth equal to or exceeding the depth of the EDv) with the peak discharge (critical storm) outlet, the designer was able to simplify and optimize the outlet while meeting both EDv criteria (see Figure 1.B.5) and peak discharge criteria (Table 1.B.5).

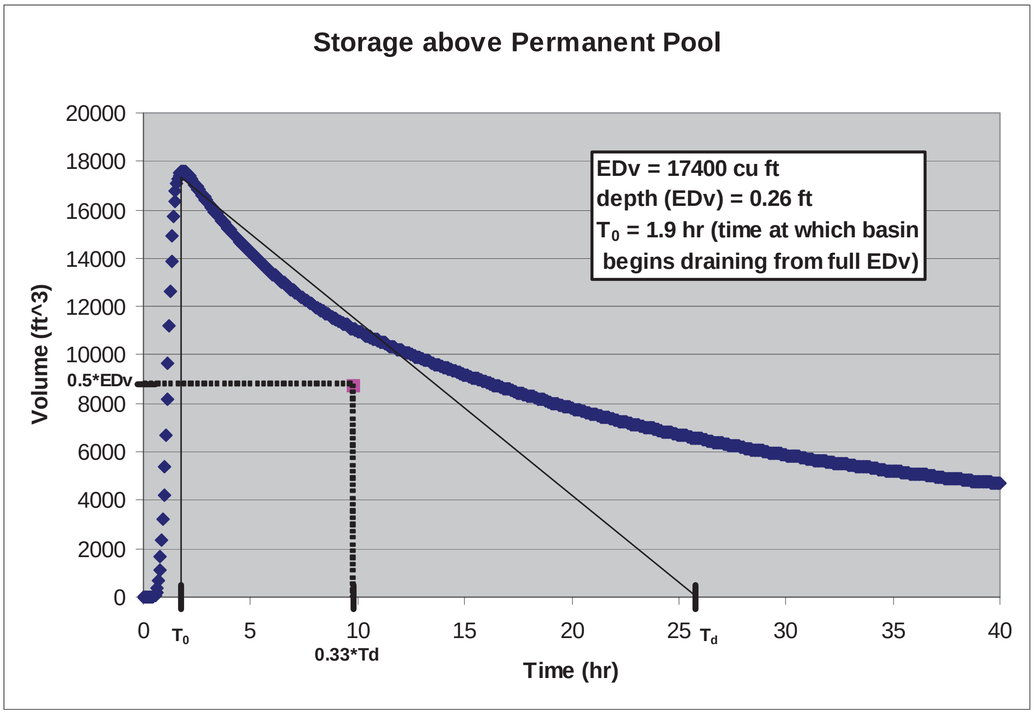


Figure 1.B.5. Wet Extended Detention Basin - Drawdown from Full EDv.

Determine storage and outlet configuration to meet peak discharge requirements

As noted under Step 2, this wet detention basin is designed to meet the Critical Storm Method (CSM) for peak discharge control as well as the WQv requirement. Storage volume must be incorporated that, with appropriate outlet design, will allow the basin to meet the following requirements:

- The peak rate of discharge from the post-construction 5-year, 24-hour event (the *critical storm*) must be less than the existing (pre-development) 1-year, 24-hour discharge peak rate
- The peak rate of discharge from the post-construction 10-, 25-, 50- and 100-year, 24-hour events must be no more than the existing (pre-development) discharge peak rate for the corresponding recurrence interval events

Proprietary stormwater modeling software was used to try a combination of stage-storage and outlet

[3] The methodology laid out in the Ohio NPDES Post Construction Q&A Document (Guidance Regarding Post-Construction Storm Water Management Requirements of Ohio; Ohio EPA, 2007) item #22.is a good starting point for selecting the EDv orifice size because it will always meet the two drawdown requirements: (1) the specified minimum drain time, Td; and (2) the outlet must not discharge more than the first half of the WQv (or EDv) in less than one-third of the drain time. A larger or smaller orifice should be considered if it will help meet other environmental, cost, or maintenance goals but must be tested for the two drawdown criteria.

configurations until the *critical storm* requirement was satisfied while considering the following:

- use best practices outlined in Section 2.6 of the Rainwater and Land Development manual
- optimize cut/fill and grading
- meet safety and aesthetic goals for the "lake" and waterfront properties

The resulting detention basin geometry is presented in Figure 1.B.4 and Table 1.B.4. The resulting outlet configuration is shown in Figure 1.B.6.

The outlet structure (see Figure 1.B.6) consists of a 3 ft by 3 ft concrete catch basin (e.g., ODOT No. 2-3) with invert at 820 MSL and 2.5'x2.5' iron grate at 828 MSL. The following comprise the outlets:

- A 30" wide orifice combined with a V-notch weir (invert 826 MSL) that controls release of both the extended detention volume (EDv) and the *critical storm* (5-year, 24-hour)
- 2.5'x2.5' iron grate (effective orifice area 490 sq. in.; invert 828 MSL) for maintenance access and to help manage discharge between the 10-yr and 100-yr, 24-hr events

The catch basin will be connected - using a 30" diameter conduit - to the 36" diameter storm sewer at the road along the north property boundary. A tailwater analysis was performed using the modeling software and the storm sewer's design elevation (invert at 818.5 MSL; 10-yr full pipe flow at 821.5 MSL) and assumed elevation for the 100-yr event (827.5 MSL).

In addition, this design includes an emergency spillway excavated into native soil with the following characteristics:

- Invert (crest) elevation of 829.2 MSL
- Spillway crest perpendicular to flow
- Level section length of 25 ft, weir length (i.e., width of crest perpendicular to flow) of 25 ft
- Exit channel flows to road ditch at elevation 827.5 MSL
- With all other outlets blocked and starting from the permanent pool elevation of 826 MSL, will safely convey the 100-yr, 24-hr event

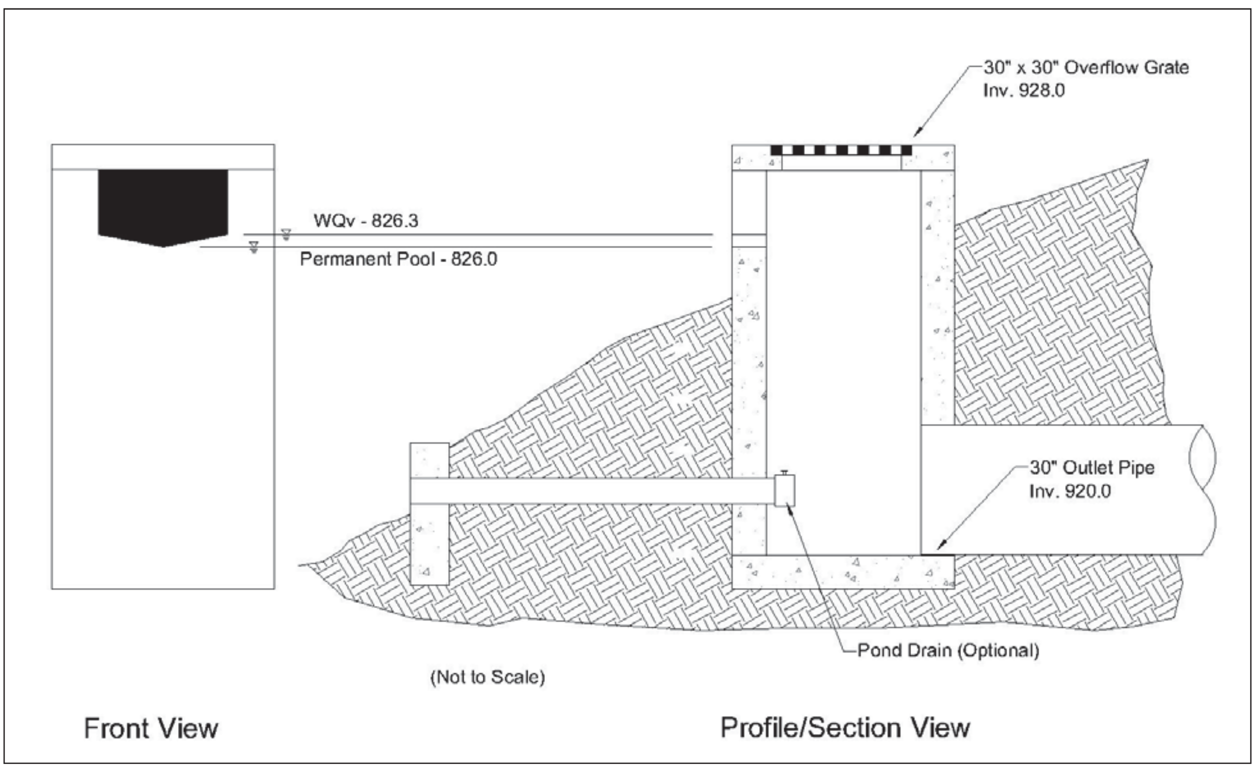


Figure 1.B.6. Outlet Configuration for Wet Extended Detention Basin (not to scale).

Step 6 - Check Design to Ensure All Requirements Are Met

From full EDv, check that EDv meets minimum 24 hour drain time, and discharges no more than 1/2 the extended detention volume, 0.5*EDv (9150 ft^3), in the first 1/3 of the drain time, 0.33*T_d (8 hr). This requirement is met and illustrated in Figure 1.A.5[4].

Check peak discharge for all events (see Table 1.B.5).

RI years	P in	$q_{post-in}$ cfs	Allowed $q_{post-out}$ cfs	Estimated $q_{post-out}$ cfs
1	2.42	38.1	16.1	7.2
2	2.90	50.4	16.1	11.1
5	3.56	67.7	16.1	15.9
10	4.07	81.3	38.6	24.0
25	4.77	100.0	48.6	32.3
50	5.32	114.7	56.6	37.3
100	5.89	130.0	65.0	41.8

Table 1.B.5. Critical Storm Method Peak Discharge Check.

[4] Note - Through trial and error, it was determined using a constant intensity 1-hour rainfall event of 0.83" depth in the hydrologic model would raise the water surface elevation of the wet basin to 826.26 providing a just-full EDv of 0.40 ac-ft (17,400 ft^3) above permanent pool, allowing evaluation of the drawdown from a full EDv (Figure 1.B.5). The depth of rainfall event necessary to just fill the EDv or WQv for other stormwater basins using CN methodology will vary based on watershed characteristics, pond geometry and outlet configuration, but can be determined through trial and error.

Section C: Extended Detention Wetland Basin

This design example illustrates the design of a extended detention wetland basin that provides water quality treatment and peak discharge control for a single family residential development, consisting of 101 residential lots on 46.0 acres (parcel and drainage area). The layout of the Beech Ridge subdivision is shown below in Figure 1.C.1.

The impervious area of the site at completion of construction is estimated to be 13.2 acres. The pre-developed site soils and flow paths are shown in Figure 1.C.2, while the post-developed flow path (limited to that used for calculations) is shown in Figure 1.C.3.   This example assumes that the local community has adopted the Critical Storm Method criteria to control peak discharges.

Figure 1.C.1. Beech Ridge Subdivision Site Plan.

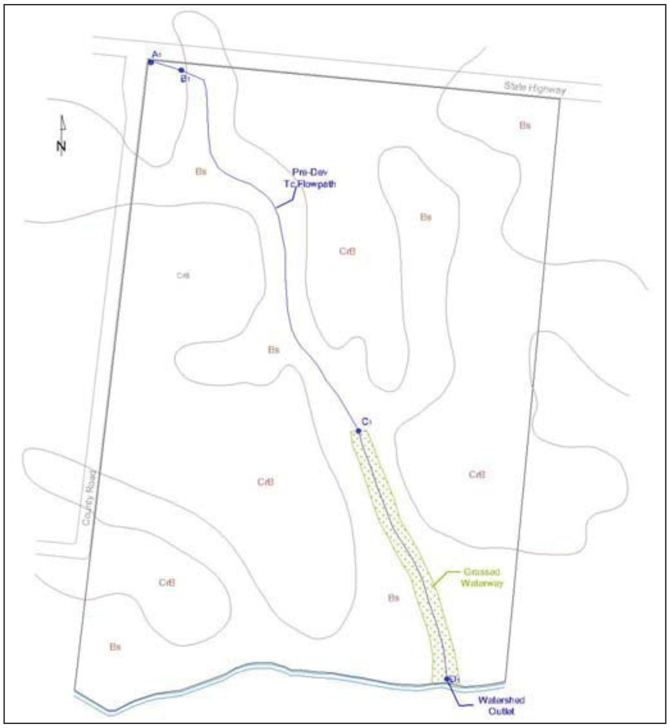


Figure 1.C.2. Pre-Development and Soils and Flow Path.

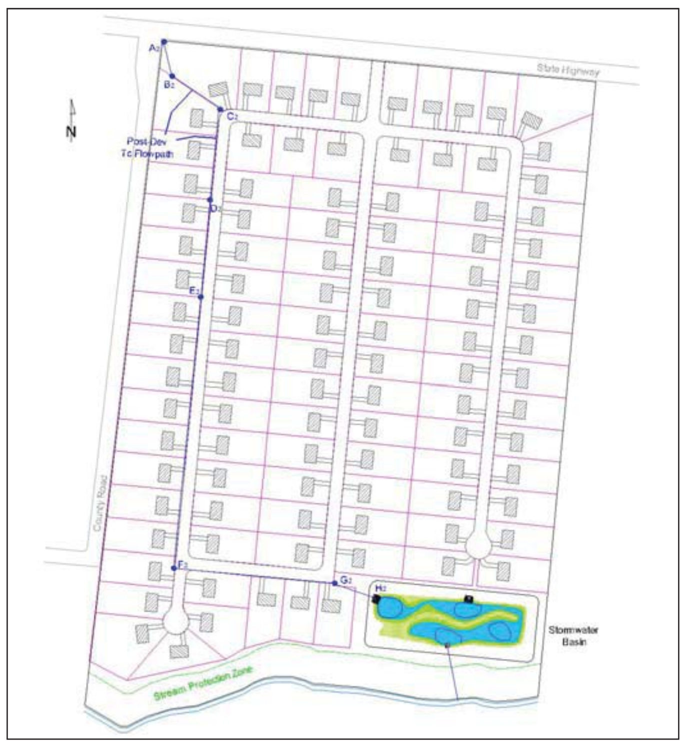


Figure 1.C.3. Post-Development Flow Path and Proposed Basin Location

Site Data
Zoning: Residential, 16,000 ft^2 minimum lot size (0.37 ac)
Total Drainage Area (A) = 46.0 ac
Estimated Impervious Area = 13.2 ac
Pre-Development Soil Types: 60% HSG-C, 40% HSG-B/D

Summary Hydrologic Data
WQv = 0.69 ac-ft

	Pre	Post
CN =	79	86
Tc =	69.5 min	25.4 min

Calculation of Preliminary Stormwater Storage Volumes and Peak Discharges

Step 1 - Calculate Water Quality Volume (WQv)

The water quality volume (WQv) is a post-construction stormwater control requirement in Ohio (OEPA-CGP, 2008). The WQv is determined according to the following equation:

$$WQv = C*P*A \quad \text{Equation 1.C.1}$$

where:

C = runoff coefficient

P = 0.75 inch precipitation depth

A = drainage area

For open water, C = 1. At this site, the surface area of the detention basin at full WQv is estimated to be 1.2 acres.

For the remainder of the site, the runoff coefficient can either be selected from Table 1 of the NPDES Storm Water Permit, or calculated using the following equation:

$$C = 0.858i^3 - 0.78i^2 + 0.774i + 0.04 \quad \text{Equation 1.C.2}$$

where i is the fraction of post-construction impervious surface.

For this site, total impervious area = 13.2 acres from a drainage area of 44.8 acres (i.e., total site drainage area - surface area of detention basin).

$$i = 13.2/44.8 = 0.295 \quad \text{Equation 1.C.3}$$

$$C = 0.858(0.295)^3 - 0.78(0.295)^2 + 0.774(0.295) + 0.04 = 0.22 \quad \text{Equation 1.C.4}$$

Therefore, the WQv is:

$$WQv = [(1.0 * 0.75\text{ in} * 1.2\text{ ac}) + (0.22 * 0.75\text{ in} * 44.8\text{ ac})] * (1\text{ ft}/12\text{ in}) \quad \text{Equation 1.C.5}$$

$$= \underline{0.69\text{ ac-ft}}$$

$$= 30,100\text{ ft}^3$$

Step 2 - Compute Peak Discharge Requirements

> Note: Peak discharge control is typically regulated through local entities (e.g. stormwater district, municipal, township or county governments). The state of Ohio recommends use of the Critical Storm Method[1] for peak discharge control, but the requirements will vary by community. Check local stormwater regulations to determine which peak discharge control method you must use.

This example uses the SCS Curve Number Methodology to perform hydrologic calculations. TR-20, HEC-HMS or other software that uses SCS procedures should provide similar results.

Tables 1.C.1 and 1.C.2 summarize the inputs necessary to determine the curve number (CN) and time of concentration (Tc) for the existing (pre-development) and proposed (post-development) conditions. The property receives no runoff from off-site. Table 1.C.3 summarizes the existing and proposed runoff depths and peak discharges for the 1-year, 24-hr through 100-year, 24-hr rainfall events.

The *critical storm* is determined from the percent increase in runoff volume from the 1-year, 24-hr storm for the proposed (post-developed) conditions when compared to the existing (pre-developed) conditions (Goettemoeller et al., 1980):

$$Percent\ \ Increase = \frac{Q_{post} - Q_{pre}}{Q_{pre}} x\,100$$

Equation 1.C.6

From Table 1.C.3, the percent increase in the 1-year, 24-hr runoff for the proposed development is:

$$Percent\ \ Increase\ = \frac{0.98 - 0.62}{0.62} x\ \ 100 = 58.1\%$$

Equation 1.C.7

For a percentage increase between 50% and 100%, the critical storm for peak discharge control is the 10 -year, 24-hr event—that is, the 10-year, 24-hr post-developed peak discharge must be less than the existing (pre-developed) 1-year, 24-hr peak discharge. These values are shown in bold type in Table 1.C.3. In addition, the post-developed peak discharge from the 25, 50 and 100 year events must be less than the existing peak discharge for each of those events.

Step 3 - Identify Other Local Development Criteria/Requirements

This site is located within a community that has incorporated a stream corridor protection requirement (i.e., stream setback) in its subdivision regulations. Review of the regulations has determined that the stream protection zone at this site extends 100 ft from the ordinary high water mark of the adjacent stream. This protection zone is noted on the map in Figure 1.C.1. All construction activities, including the wetland stormwater basin and embankment, must be outside of the stream protection zone. Also note this stream protection area, since it does not drain to the detention facility, was excluded from the hydrologic analysis.

[1] The Critical Storm Method is a set of criteria for controlling the peak discharge of stormwater from large storm events (1 - 100 yr recurrence interval) recommended by ODNR-DSWC since 1980. See Goettemoeller, R.L., D.P. Hanselmann, and J.H. Bassett. 1980. Ohio Stormwater Control Guidebook. Ohio Department of Natural Resources, Division of Soil and Water Districts, p47.

Peak Discharge Summary

Project: Beech Ridge Subdivision

	Cover Description	Soil Name	Hydrologic Group	Drainage Y/N	CN	Area (acres)
Existing Condition Site Only	Row crop, SR + CR (good condition)	Crosby	C		82	27.6
	Row crop, SR + CR (good condition)	Brookston	B/D	Y	75	18.4
	Pre-development Conditions - All				**79**	**46.0**
Proposed Condition Site Only	**Cover Description**	**Soil Name**	**Hydrologic Group**		**CN**	**Area (acres)**
	Impervious Area				98	13.2
	Open space (good condition)	Crosby	D		80	18.5
	Open space (good condition)	Brookston	D		80	12.3
	Open Water				98	2.0
	Post-development Conditions - All				**86**	**46.0**

Table 1.C.1. Curve Number (CN) for existing (pre-developed) condition.

	Segment	Flow Type	Surface Cover	Mannings n	Length ft	Slope %	Velocity ft/s	Tt min
Existing Condition Site Only	A_1 to B_1	Overland - sheet	Min Tillage	0.17	100	1.2		14.8
	B_1 to C_1	Overland - shallow conc	Min Tillage	0.1	1250	0.75	0.44	47.6
	C_1 to D_1	Overland - shallow conc	Grassed waterway	0.05	750	1.2	1.8	7.1
	Total	**Pre-developed**			**2100**			**69.5**
Proposed Condition Site Only	**Segment**	**Flow Type**	**Surface Cover**	**Mannings n**	**Length ft**	**Slope %**	**Velocitiy ft/s**	**Tt min**
	A_2 to B_2	Overland - sheet	Grass	0.24	100	1.5		17.8
	B_2 to C_2	Overland - shallow conc	Grassed waterway	0.05	160	1.5	2.0	1.3
	C_2 to D_2	Pipe - storm drain (15”)	Pipe	0.013	250	0.5	3.7	1.1
	D_2 to E_2	Pipe - storm drain (18”)	Pipe	0.013	270	0.5	4.2	1.1
	E_2 to F_2	Pipe - storm drain (24”)	Pipe	0.013	750	0.5	5.1	2.5
	F_2 to G_2	Pipe - storm drain (30”)	Pipe	0.013	450	0.5	5.9	1.3
	G_2 to H_2	Pipe - storm drain (36”)	Pipe	0.013	130	0.5	6.7	0.3
	Total	**Post-developed**			**2150**			**25.4**

Table 1.C.2. Time of Concentration (Tc) for existing (pre-developed) and proposed (post-developed) condition.

RI years	P in	Q_{pre} in/acre	Q_{post} in/acre	q_{pre} cfs	q_{post} cfs
1	2.17	0.62	0.98	12.1	42.8
2	2.59	0.90	1.32	18.3	58.0
5	3.18	1.32	1.82	28.1	80.4
10	3.67	1.70	2.25	36.7	99.4
25	4.35	2.25	2.87	49.2	126.2
50	4.91	2.72	3.38	59.9	148.4
100	5.50	3.24	3.94	71.3	171.9

Table 1.C.3. Summary runoff depth (Q) and peak discharge (q) for existing (pre-developed) and proposed (post-developed) condition with critical storm (bold type).

Step 4 - Determine if the Development Site and Soils Are Appropriate for the Use of an Extended Detention Wetland Basin

The site drainage area is 46.0 acres. Brookston and Crosby soils are suitable for creation of an extended detention wetland. The subsoil is silty clay loam derived from high-lime glacial till and has slow permeability. This subsoil is suitable material for construction of the embankment for the stormwater basin.

It is known that subsurface tiles currently drain the proposed property. All tiles need to be removed from the wetland basin site[2].

Step 5 - Determine Pond Location and Develop Preliminary Geometry to Meet WQv and Peak Discharge Requirements

The proposed location of the stormwater basin (see Figure 1.C.3) reflects the best combination of characteristics (landscape position, access to outlet, minimize earth moving, appropriate soils, etc.) for siting the basin. Existing ground elevation at the proposed pond outlet is 907 MSL. The invert of the receiving stream at the proposed discharge point is 896 MSL.

The basin will be designed to include a permanent pool, an extended detention volume equivalent to the WQv, and the storage necessary to control the peak discharge rate. [For more information on siting and planning a wetland basin, see section 2.6.]

An analysis of site hydrology (drainage area/wetland surface area ratio >>20, HSG-D soil with seasonal high water table, etc.) has determined that a permanent pool equivalent to the WQv (~0.69 ac-ft) up to 2 ac-ft should be sufficient to maintain basic wetland hydrology and function. In addition, an additional sediment storage volume equal to 20% of the WQv (0.2*WQv = 0.2*0.69 = 0.14 ac-ft) is added to the permanent pool with this volume concentrated in the forebay.

A preliminary plan view of the basin layout (Figure 1.C.4) reflects the following:

- permanent pool (includes forebay and outlet micropool) with a volume in excess of 1.2*WQv
- permanent pool forebay equal to 0.2* WQv and a minimum depth of 3 ft
- permanent micropool at outlet with a minimum depth of 3 ft
- total area of deep pools (including forebay and outlet mircropool) representing between 20 and 25 percent of total permanent pool surface area with deep pools interspersed through wetland to provide refugia and wetland function during drought periods - depth of deep pools should range between 18 and 36 (or more) inches[3]
- balance of permanent pool with average depth of 0.75 ft, and range of depths from 6” to 18”
- a low constructed peninsula, with an elevation approximately 1 ft above the extended detention (WQv) storage volume, to extend the flow path and minimize short-circuiting during the WQv event
- maximum 4:1 side slopes for safety and maintenance
- an emergency spillway constructed in native soil (i.e., not located in the constructed embankment)

Note: The high organic matter topsoil should be removed and stockpiled before excavation and construction of the wetland, and then replaced on peninsulas and benches.

[2] Functional drainage systems are essential for the productivity of agriculture in much of Ohio, and to prevent flooding of upgradient property. It is the responsibility of the developer to maintain drainage infrastructure (surface and subsurface drainage mains) disrupted by construction activities. As an example, if a subsurface tile main conveys water from upgradient properties, that main should be protected or re-routed to maintain the same drainage capacity.

[3] Recent guidance from North Carolina (Hunt et al, 2007) recommends “deep pools (including the forebay) should occupy between 20 and 25 percent of the total wetland surface area”. For most wetlands this will result in a permanent pool volume (ac-ft) between about 1.1 and 1.3 times the surface area (acres) of the permanent pool.

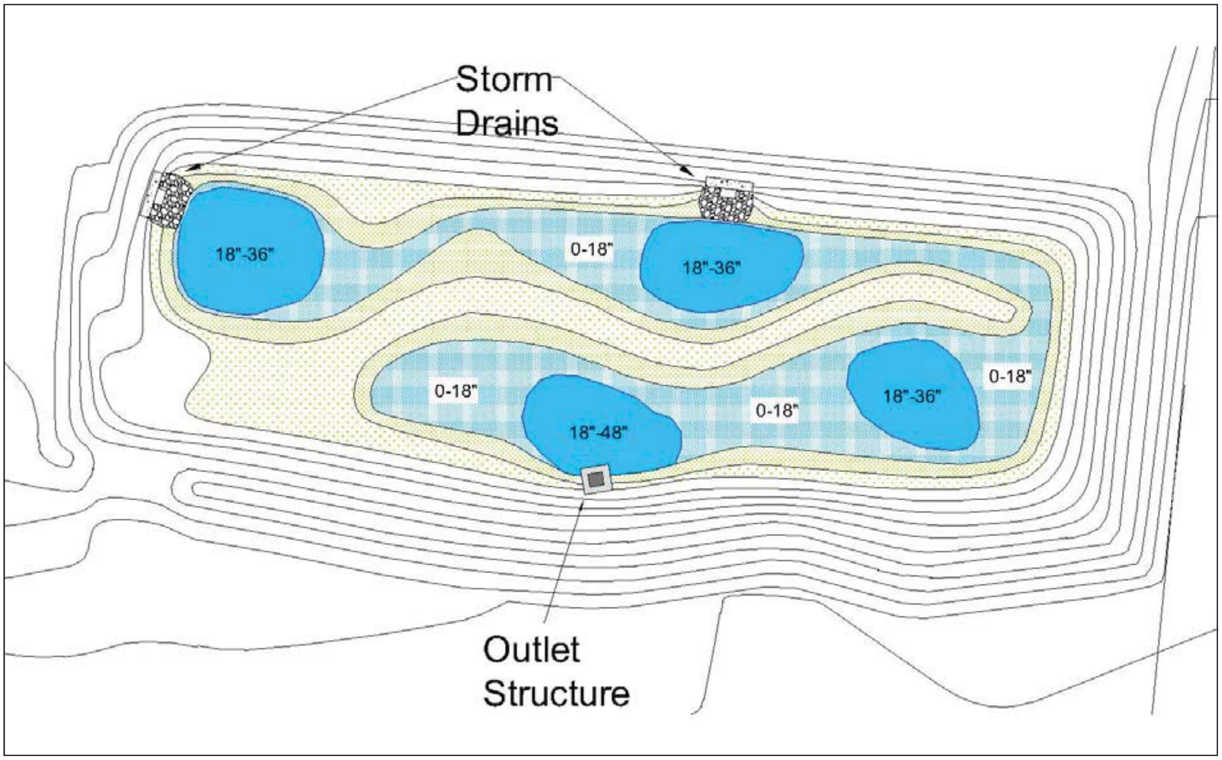


Figure 1.C.4. Preliminary Plan View of Wetland (not to scale).

Elevation MSL (ft)	Surface Area (acre)	Average Area (acre)	Incremental Depth (ft)	Incremental Volume (ac-ft)	Cumulative Volume (ac-ft)	Vol above Perm Pool (ac-ft)
900.0	0.08	-	-	-	-	-
902.5	0.16	0.12	2.5	0.30	0.30	-
903.0	0.24	0.20	0.5	0.10	0.40	-
903.5	0.48	0.36	0.5	0.18	0.58	-
904.0	0.74	0.61	0.5	0.31	0.89	-
904.7	1.24	0.99	0.7	0.69	1.58	0.69
905.0	1.50	1.37	0.3	0.41	1.99	1.10
906.0	1.60	1.55	1.0	1.55	3.54	2.65
907.0	1.71	1.65	1.0	1.65	5.19	4.30
908.0	1.82	1.76	1.0	1.76	6.95	6.07
909.0	1.93	1.87	1.0	1.87	8.82	7.94
910.0	2.05	1.99	1.0	1.99	10.81	9.93
911.0	2.20	2.13	1.0	2.13	12.94	12.05

Table 1.C.4. Stage-Area-Storage Information for Wetland Basin.

Set elevations for pond structures

- The basin bottom is set at elevation 900.0
- To allow gravity flow for the pond drain, set the riser invert at 898.0
- The outfall at the receiving stream has invert elevation 896.5

Set permanent pool and WQv water surface elevations

A stage-area-storage table (Table 1-4) reflects geometry of the stormwater wetland basin (Figure 1-3) designed to meet permanent pool, extended detention WQv and peak discharge control requirements.

- To meet NPDES Construction Stormwater Permit minimums, the permanent pool, surface elevation 904.0, is sized to exceed 1.2*WQv = 1.2*0.69 ac-ft = 0.83 ac-ft (see footnote below)
- The extended detention WQv of 0.69 ac-ft above permanent pool has a top elevation of approximately 904.7

Calculate required orifice size for 24-hour drawdown of WQv

The controlling parameters are WQv = 0.69 ac-ft, depth of WQv = 0.7 ft, and minimum drain time, t_d, of 24 hours. Note that “the outlet structure for the post-construction BMP must not discharge more than the first half of the WQv in less than one-third of the drain time” (p22, NPDES Storm Water Construction General Permit).

The average discharge rate for the WQv is:

$$Q_{avg} = \frac{WQv}{t_d} = \frac{(0.69\ ac \cdot ft)\left(\frac{43560\ ft^2}{1\ ac}\right)}{(24\ hr)\left(3600\ \frac{s}{hr}\right)} = 0.35\ cfs$$ Equation 1-C-8

The discharge equation for an orifice is:

$$Q = ca\sqrt{2gh}$$ Equation 1-C-9

By rearranging, we can estimate needed orifice area:

$$a = \frac{Q}{c\sqrt{2gh}}$$ Equation 1-C-10

Using an orifice coefficient, c = 0.6, and average head, h = d/2 = (0.7 ft)/2 = 0.35 ft, the required orifice size is:

$$a = \frac{0.35\ \frac{ft^3}{s}}{0.6\sqrt{2(32.2\ \frac{ft}{s^2})(0.35\ ft)}} = 0.12\ ft^2$$ Equation 1-C-11

Resulting in an orifice diameter of:

$$d = \left(\frac{4a}{3.14}\right)^{0.5} = \left[\frac{4(0.12\ ft^2)}{3.14}\right]^{0.5} = 0.39\ ft \times \frac{12}{1\ ft} = 4.7\ in$$ Equation 1-C-12

This estimate is a good starting point for selecting the WQv or EDv orifice size because it will always meet the two drawdown requirements: (1) the specified minimum drain time, Td; and (2) the outlet must discharge less than the first half of the WQv in the first one-third of the drain time (8 hours in this case). A larger or smaller orifice should be considered if it will help meet other environmental, cost, or maintenance goals but must be tested for the two drawdown criteria. In this situation, trial and error showed that a 6.0” diameter orifice will meet the above two drawdown requirements (see Figure 1.C.4) and will be used as the WQv outlet.

Determine storage and outlet configuration to meet peak discharge requirements

As noted under Step 2, this wetland basin is designed to meet the Critical Storm Method (CSM) for peak discharge control as well as the WQv requirement. Additional storage volume must be added that, with appropriate outlet design, will allow the basin to meet the following requirements:

- The peak rate of discharge from the post-construction 10-year, 24-hour event (the *critical storm*) must be released at the existing (pre-development) 1-year, 24-hour discharge rate
- The peak rate of discharge from the post-construction 25-, 50- and 100-year, 24-hour events must be released at the existing (pre-development) discharge rate for the corresponding recurrence interval events

Proprietary stormwater modeling software was used to try a combination of stage-storage and outlet configurations until the Table 1.C.5 requirements were satisfied while considering the following:

- maximize wetland function
- minimize the "footprint" of the basin
- optimize cut/fill

RI years	P in	$q_{post\text{-}in}$ cfs	Allowed $q_{post\text{-}out}$ cfs
1	2.17	42.7	12.1
2	2.59	57.9	12.1
5	3.18	80.2	12.1
10	3.67	99.1	12.1
25	4.35	125.9	49.2
50	4.91	148.0	59.9
100	5.50	171.4	71.3

Table 1.C.5. Critical Storm Method Peak Discharge Requirements.

The resulting wetland basin geometry is presented in Figure 1.C.3 and Table 1.C.4. The resulting outlet configuration is shown in Figure 1.C.5.

The outlet structure consists of a 4 ft by 4 ft concrete catch basin (e.g., ODOT No 2-4) with invert at 899 MSL and 3.7'x3.7' iron grate at 908.33 MSL. The following comprise the outlets:

- 36" barrel outlet with invert at 899 MSL
- 6.0" extended detention (WQv) orifice (invert 904 MSL) with submerged entrance
- Two (2) 12" diameter orifices (invert 904.7 MSL) that control release of the *critical storm* (10-year, 24-hour)
- Four 36" L x 9" H rectangular orifices (invert 907.25 MSL) and 3.7'x3.7' iron grate (invert 908.33) with 868 in^2 of clear opening area that control release of the 25- through 100-year, 24-hour events

In addition, this design includes an emergency spillway excavated into native soil that has the following characteristics:

- Invert (crest) elevation of 909.3 MSL
- Level section length of 25 ft, weir length (i.e., crest width) of 30 ft
- Spillway crest perpendicular to flow
- Exit channel aligned with level section well beyond downstream toe of dam, and a 4 percent slope
- With all other outlets blocked and starting from the permanent pool elevation of 904 MSL, will safely convey the 100-yr, 24-hr event with 1 ft freeboard from top of embankment

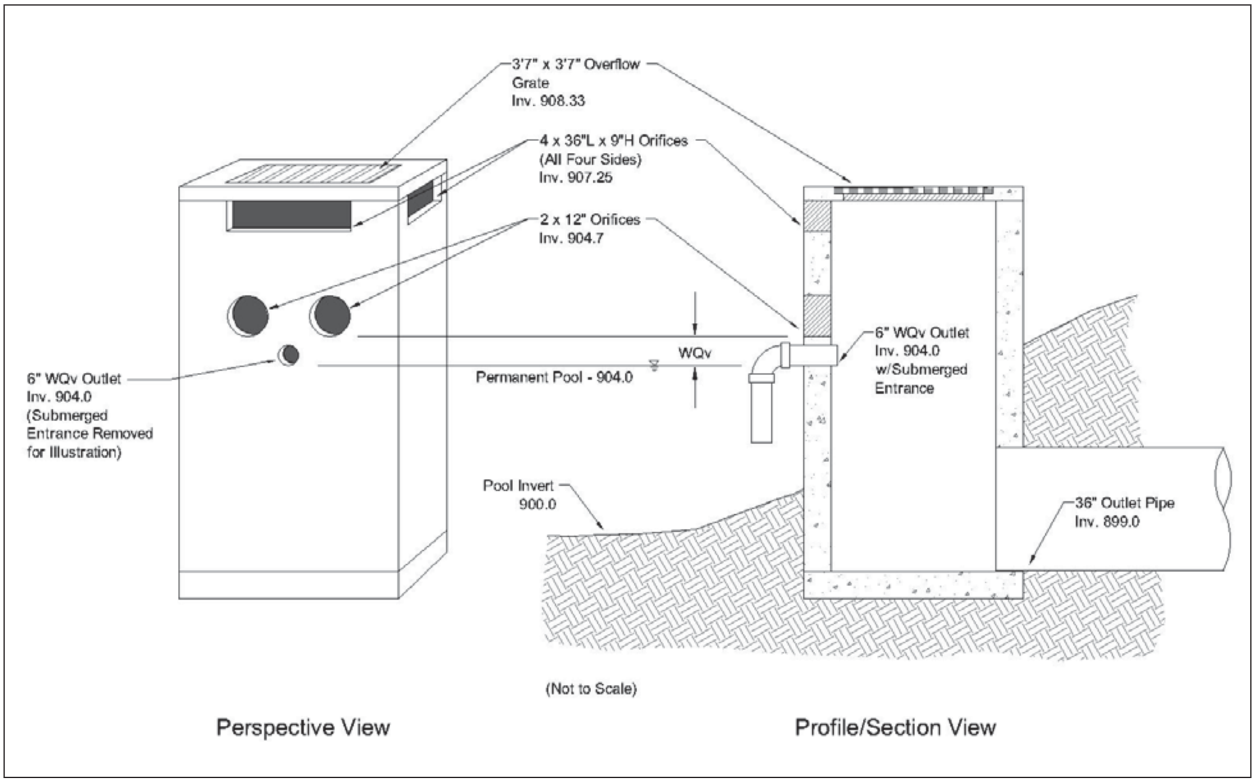


Figure 1.C.5. Outlet configuration for Wetland Basin (not to scale).

Step 6 - Check Design to Ensure All Requirements Are Met

From "brimfull", check that WQv meets minimum 24 hour drain time, and discharges no more than 1/2 the water quality volume, 0.5*WQv (= 15,550 ft^3), in the first 1/3 of the drain time, 0.33*T_d (8 hr). Figure 1.C.4 shows the wetland basin meets this requirement.

Check peak discharge for all events. Table 1.C.6 shows the wetland basin meets the peak discharge requirements.

RI years	P in	$q_{post\text{-}in}$ cfs	Allowed $q_{post\text{-}out}$ cfs	Estimated $q_{post\text{-}out}$ cfs
1	2.17	42.7	12.1	5.1
2	2.59	57.9	12.1	7.6
5	3.18	80.2	12.1	10.2
10	3.67	99.1	12.1	12.1
25	4.35	125.9	49.2	26.5
50	4.91	148.0	59.9	42.7
100	5.50	171.4	71.3	62.4

Table 1.C.6. Critical Storm Method Peak Discharge Check.

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Appendix 2: NPDES Permits for Stormwater Discharges from Construction Sites

NPDES permits are the primary means by which the United States Environmental Protection Agency (USEPA) regulates discharges of polluted waters into our streams and lakes, and are a requirement of the federal Clean Water Act (CWA). Historically, NPDES permits were primarily issued to municipal or industrial facilities that discharged municipal wastewater or process wastewater to waters of the United States, but due to the increasing problem of polluted urban runoff, including construction site runoff, Congress amended the Clean Water Act (CWA) in 1987 to address stormwater discharges. On November 16, 1990, the USEPA published the requirements of the Phase I Stormwater NPDES Permit program in the ***Federal Register*** (40 CFR 122.26). Ohio, as a NPDES delegated state, designates Ohio EPA as the agency which implements the federal stormwater program in Ohio.

Phase I of the Stormwater NPDES Permit program regulates stormwater runoff (1) Municipal Separate Storm Sewer Systems (MS4) having a service population of 100,000 or more; (2) industrial facilities which tend to have material storage, handling or processing areas outdoors; and (3) construction activity which disturbs 5 or more acres in the larger common plan of development or sale. Sites regulated under Phase I are required to develop and implement Stormwater Pollution Prevention Plans (SWP3s) in accordance to the terms and conditions of an NPDES permit

> *Useful Definitions:*
>
> *Construction activity is defined as any grading, grubbing, filling, clearing or excavating for non-silvicultural or non-agricultural purposes.*
>
> *The larger common plan of development or sale is defined as a contiguous area where multiple separate and distinct construction activities are occurring under one "plan". The "plan" is broadly defined as any announcement or piece of documentation (including a sign, public notice or hearing, sales pitch, advertisement, drawing, permit application, zoning request, computer design, etc.) or physical demarcation (including boundary signs, lot stakes, surveyor markings, etc.) indicating that construction activities may occur on a specific plot.*

On December 8, 1999, the USEPA expanded the NPDES Stormwater Permit program by designating additional sources of stormwater for regulation. Referred to as Phase II, these regulations affect stormwater discharges from two sources, which affect the construction industry: small construction sites and small municipal separate storm sewer systems (MS4s). These entities were required to obtain NPDES permit coverage by March 10, 2003.

Ohio EPA Construction Site Program

Under Phase I, stormwater runoff from large construction sites, disturbing 5 acres or more in the larger common plan of development or sale, were required to comply with the terms and conditions of an NPDES permit. Under Phase II, small construction sites must also comply with the terms and conditions of an NPDES permit. Small construction sites are defined as those that disturb between 1 and 5 acres in the larger common plan of development or sale. Thus, in essence, all non-silvicultural or non-agricultural construction activities, which disturb 1 or more acres in the larger common plan of development or sale, are required to comply with an NPDES permit after March 10, 2003. The only small construction activity, which is exempted under Phase II, is routine ditch or stormwater facility maintenance that will restore the original grade or capacity. Stormwater or ditch maintenance disturbing 5 or more acres would require NPDES permit coverage. NPDES permit requirements apply to all construction activities throughout the State of Ohio, regardless of whether they are within an area served by a phase II municipal separate storm sewer system
or not.

Phase II provides for permit waivers for small construction activity only (1 to 5 acres in the larger common plan of development or sale). A waiver can be obtained if <u>either</u>:

- The rainfall erosivity factor ("R" in the Revised Universal Soil Loss Equation - RUSLE) is less than five (5) during the period when the construction activity will occur. "R" varies depending on geographic location and is dependent on the time of year that construction activities will occur and the amount of time a site will be left bare. Data for Ohio indicates that to qualify for this waiver, construction activities will have to be conducted between November and March and must be initiated, completed and stabilized within a three-week time period. As such, it is not expected that many, if any, development sites in Ohio will qualify for this waiver. Appendix A of the Ohio EPA General Stormwater NPDES Permit for Construction Activities provides the worksheets for calculating the R Factor for a specific project. It can be obtained from Ohio EPA or can be downloaded from the following website: *http://www.epa.state.oh.us/dsw/storm/index.html*
- <u>Or</u>, construction will occur within an area where controls are not needed based on a Total Maximum Daily Load (TMDL), or equivalent study, for the local waterbody. TMDLs are being developed for all impaired watersheds in Ohio and should be completed by 2015. TMDL is a method of allocating pollutants amongst the various sources of pollutants such that the receiving stream will meet water quality standards. To see if a TMDL has been completed for a waterbody of interest, contact the Ohio EPA. See the following website: *http://www.epa.state.oh.us/dsw/tmdl/*.

If you feel that your site qualifies for a waiver, a permit waiver form must be submitted to Ohio EPA. However, be aware that local ordinances may still require that you obtain a permit from local authorities even if you qualify for a waiver from Ohio EPA.

Requirements of the General Stormwater NPDES Permit for Construction

The NPDES stormwater permit program is largely administered via general permits developed to cover an entire industry or portion of an industry, such that all sites within that sector have the same requirements. Coverage under the Ohio EPA General Stormwater NPDES Permit for Construction Activities is obtained by filing a Notice of Intent (NOI). A site vicinity map on 8.5″ x 11″ paper with the boundaries of the area intended to be covered by the NPDES permit must accompany the NOI. The NOI and all other forms associated with the NPDES permit program can be obtained from the Ohio EPA, or downloaded from their website at: *http://www.epa.state.oh.us/dsw/storm/index.html*. By filing an NOI, a developer or site operator is certifying that they have developed a Stormwater Pollution Prevention Plan (SWP3) and will comply with the requirements of the NPDES permit.

The requirements of the Ohio EPA General Stormwater NPDES Permit for Construction Activities are summarized below. However, be aware that the Director of Ohio EPA has the authority to deny coverage under the general permit and require coverage under an individual permit for sensitive development sites or for chronically non-compliant developers. Under an individual permit, site-specific requirements may be more stringent than those found in the general permit and may include runoff monitoring criteria and pollutant discharge limits. Some watershed areas, such as the Big Darby Creek, may have different NPDES general permits with greater requirements, such as additional pollution or hydrologic controls or stormwater pollution prevention plan requirements. In any case, you are encouraged to consult the Ohio EPA, Division of Surface Water for the latest NPDES general permits information, copies can be downloaded from their website at *www.epa.state.oh.us/dsw/permits/gpfact.html.*

Administrative Requirements
File the NOI with Ohio EPA at least 21 days prior to the start of any construction activities.
If project is within an urbanized area (UA) or area where there is local approval of sediment and erosion control plans, a copy of the NOI must also be submitted to the local approving agency.
No construction activities may begin until you receive a Director's Authorization letter granting coverage under the NPDES permit.
A copy of the NOI, Director's Authorization letter and stormwater pollution prevention plan (SWP3) must be kept on site during working hours.
SWP3 must be developed prior to the initiation of construction activities.
A copy of the SWP3 must be made available to Ohio EPA, MS4 operator or local agency responsible for reviewing and approving such plans within 10 days of written request.
Amend the SWP3 whenever there is a change in site design, construction, operation or maintenance that requires the installation of best management practices (BMPs) or modifications to existing BMPs.
While the SWP3 is not typically submitted to Ohio EPA at the time the NOI is filed, Ohio EPA may review the SWP3 at any time. If Ohio EPA requests changes to the SWP3 in writing, they must be made within 7 days of the request.
Maintain a written document acknowledging understanding of the SWP3 and responsibilities under the plan signed by all contractors and subcontractors involved in the implementation of the SWP3.

Requirements Regarding Erosion Controls
BMPs, which preserve the existing natural site condition as much as feasible are required to be utilized in the SWP3, such as phased construction to minimize land disturbed at any one time, preserving riparian areas and leaving existing vegetation in place for as long as possible.
Stabilization of disturbed areas must be initiated within 7 days of reaching final grade.
Areas within 50 feet of a stream (including intermittent streams) must be stabilized within 2 days of the most recent disturbance.
Temporary stabilization of disturbed areas that will be reworked, but not for 21 days or more from the date they were last disturbed, must be initiated within 7 days of last disturbance.
Disturbed areas intended to be left idle over winter must be stabilized prior to the onset of winter weather, i.e., sustained snow cover or frozen ground conditions.
Special measures must be taken as necessary to stabilize drainage channels and stormwater outfalls.
Runoff must be diverted away from disturbed areas and steep slopes wherever practicable.

Requirements Regarding Sediment Controls
Plan sediment controls for any area that will remain disturbed for 14 days or longer.
Sediment controls must pond runoff in order to be considered functional.
Sediment ponds (including temporarily modified permanent ponds) and perimeter sediment barriers must be installed as the first step of grading and within 7 days from the start of grubbing and remain functional until all upslope development areas are restabilized.
Sediment ponds must be utilized to control concentrated flows of runoff.
Sediment ponds must be implemented for all common drainage areas with 10 or more acres disturbed at one time and whenever the capacity of sediment barriers is exceeded.
Sediment ponds must provide a minimum storage volume of 67 cubic yards per acre of total contributing drainage area.
The length-to-width ratio between the inlet(s) and outlet(s) of sediment ponds must be 2:1 or longer. Baffles must be implemented to provide this ratio if the pond cannot be configured to do so.
Sediment ponds cannot be deeper than 5 feet.
No structural sediment controls may be located in a stream. As such, permanent storm water basins located "in-line" with a stream may not be utilized as a sediment pond. Sediment barriers may not be placed across stream channels.
Sediment barriers, such as silt fence or diversions, must be implemented to prevent silt from entering water resources that run through the property.
Sediment barriers must be implemented to protect adjacent properties.
Silt fence is only allowed to be used to control sheet flow runoff from limited drainage areas. The permissible drainage area per 100 linear feet of silt fence is dependent on the slope but is no more than 0.5 acre. Silt fence can not be used to control drainage areas with a slope of greater than 50%.
No more than 10 acres may drain to a diversion.
Inlet protection must be implemented to prevent sediment from entering the storm drain system, unless that system discharges to a sediment pond.

Requirements for Controls of Other Wastes
No solid or liquid waste, including building materials or their packaging, shall be discharged in stormwater runoff.
Concrete trucks are not permitted to wash out directly into storm sewers, streams or drainage channels.
Off-site tracking of sediments by construction vehicles must be minimized.
Waste disposal via open burning is prohibited where not permitted under the State of Ohio opening burning laws.
Contaminated soils or soils where construction site chemicals have been spilled must be removed from the site and disposed of in accordance with federal, state and local regulations.
Stormwater that comes in contact with contaminated soils, or solid & industrial waste must be collected and disposed of as a wastewater.
Fuel tanks and drums or other containers holding construction site chemicals must be stored within a diked area.
Sediment-laden trench or groundwater must pass through a sediment-settling pond, or be dewatered in place using a sump pit, filter bag or other comparable method, prior to being discharged from the site.
Trench and ground water free from sediment or other pollutants may be discharged without treatment, provided this water does not become pollutant-laden by traversing over disturbed soils or other pollutant sources.

Requirements for Post-Construction Stormwater Management
Describe post-construction BMPs and the technical basis for their selection. The rationale must address impacts on stream channel and floodplain morphology, hydrology and water quality. A mix of structural and non-structural BMPs should be chosen whenever possible.
The SWP3 must contain detail drawings for all structural post-construction BMPs.
An operating and maintenance plan for all structural post-construction BMPs must be developed by the permittee and presented to the post-construction site operator prior to termination of NPDES permit coverage. Maintenance plans must include measures for disposing of the pollutants that collect within the BMPs.
Structural post-construction BMPs are required for all projects that disturb 5 or more acres in the larger common plan of development or sale. Structural post-construction BMPs must be designed to capture and treat the Water Quality Volume (VWQ) plus an additional 20% of the VWQ.
Redevelopment projects are required to either reduce the existing, pre-construction impervious area of the site by 20% or capture and treat 20% of VWQ.
Linear projects, which do not creation new impervious surfaces, are exempt from post-construction storm- water management requirements, although they minimize the number and width of stream crossings.

The NPDES permit also places requirements on the maintenance of BMPs and requires an on-going evaluation of the site to assure compliance with the NPDES permit.

Maintenance Requirements
All BMPs must be maintained in a functional condition until all upslope areas they control are permanently restabilized.
Qualified personnel (provided by the developer) must inspect all BMPs at least once every 7 days and within 24 hours of a 0.5" or greater rainfall within any 24-hour period and determine if the SWP3 has been properly implemented.
Written reports summarizing inspection results must be made available upon request. Reports must include: date of inspection, name and qualifications of the inspector, weather conditions, locations where in-stream or off-site sedimentation was observed, locations of BMPs needing maintenance, locations of BMPs failing to operate correctly or provide adequate protection, or location of areas in need of additional BMPs not in place at the time of inspection.
The reports must identify incidences of non-compliance with the NPDES permit. Where a report does not identify incidences of non-compliance, the report must contain a certification that the site is in compliance at the time of inspection.
Maintenance or repair of BMPs must be completed within 3 days of the date of the inspection that revealed they were deficient. For sediment ponds, repair or maintenance is required within 10 days of the date of the inspection.
When inspections reveal that a BMP is not effective and that another, more appropriate BMP is required, the SWP3 must be amended and the more appropriate BMP must be installed within 10 days of the inspection that revealed the deficiency.
When the inspection reveals that a BMP depicted on the SWP3 has not been installed, but is required to provide adequate control at the site, it must be installed prior to the next storm event, which produces runoff, but in no case later than 10 days from the date of inspection, which revealed the deficiency.
The reports must be maintained for three (3) years following the submittal of a Notice of Termination.

Permit Closure Requirements
Once a site reaches final stabilization and construction activities have ceased, NPDES permit coverage is terminated by filing a notice of termination (NOT). The NOT must be filed within 45 days of reaching final stabilization.
Final stabilization is defined as establishing a vegetative ground cover of at least 70% growth density, or other means of permanent stabilization, over the entire area disturbed by construction activities.
Final stabilization also requires that all temporary sediment and erosion controls be removed from the property and all sediment that was trapped by those controls to be permanently stabilized to prevent further erosion.

Stormwater Pollution Prevention Plans (SWP3s)

The selection of Best Management Practices (BMPs) within the SWP3 must follow the recommendations in this manual or other accepted BMP standards manual acceptable to Ohio EPA. Typically, a SWP3 is a combination of a narrative, drawings, plan notes and inspection reports. A SWP3 must provide BMPs for (1) sediment and erosion control, (2) controls for pollutants other than sediments, and (3) post-construction stormwater management. The SWP3 is not complete until all three areas have been addressed. The SWP3 must contain the following information:

Narrative Information
Description of the nature and type of construction activity, which 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 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.
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 the NPDES permit (see subsection titled Maintenance Requirements above).

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 (yd3) 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.
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.

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 timely way. All of this information should not be crowded onto one page of the plans, which will make it difficult to read and understand. The SWP3 informs the contractor what practices to install, when to install them, where to install them, how to build them correctly and how they shall be maintained. As such, proper plans coordinate the required practices with the various stages or phases of construction.

When designing a SWP3, it is important to produce a document that incorporates effective stormwater strategy with the site development. The needs of construction and the requirements for environmental protection are not mutually exclusive. Proper planning is the key to this challenging task. In particular, the SWP3 not only specifies the practices used while the site is under construction, but also assures that the post-construction stormwater strategy and water resource protection has been integrated into the design of the development. Strategies such as minimizing imperviousness, maintaining or re-establishing naturally vegetated corridor along streams, and stream channel restoration are considered during the planning stage of the development.

Developing a adequate SWP3 requires recognizing that development sites are dynamic, each having unique conditions that may affect development and implementation of practices. The SWP3 must be responsive to the constantly changing topography of the construction site. Because it is difficult for site designers to fully foresee the conditions that will be present on the site, and construction means and methods used by the contractor, the developer, engineer and contractors should review the plans prior to start of construction activities to work out foreseeable issues before earth is disturbed.

Developments that are Subdivided or Sold in Parcels

The NPDES permit recognizes that developments that are subdivided and sold off in parcels require special considerations. As such, a developer must be aware of the following requirements when dealing with subdivided properties:

- The NPDES permit allows a developer to transfer permit compliance responsibilities to the parties that purchase lots within a development. This is accomplished when the party that purchases the lot files an Individual Lot Notice of Intent with Ohio EPA. That party is now responsible for permit compliance on that lot. Note that this transfer of responsibility is not automatic upon sale. If the developer does not assure that an Individual Lot NOI has been filed, he will retain compliance responsibilities on the lot. There is no fee to file an Individual Lot NOI.
- For subdivided developments where the SWP3 does not call for a centralized sediment control capable of controlling multiple individual lots, a detail drawing of a typical individual lot showing standard individual lot erosion and sediment control practices must be provided in the developer's SWP3.
- The developer's SWP3 and a site map identifying individual lots must be made available to the parties, which purchase lots within the development.
- Permit coverage can be terminated if, and only if, all areas still owned by the developer are at final stabilization and all areas no longer owned by the developer have obtained their own NPDES permit coverage by filing an Individual Lot NOI.

In some cases, a development is sold in whole to another developer or to one large homebuilding company. In these cases, permit transfers are usually a more appropriate means of transferring permit compliance responsibilities. A permit transfer form must be filed with Ohio EPA at least 60 days prior to the proposed transfer date. If a site is sold off in large blocks (but not in whole) to other developers and large homebuilding companies, those other developers or homebuilding companies should file their own Notices of Intent (not Individual Lot NOIs) to cover those blocks. Once all NOIs have been received by Ohio EPA to cover the blocks, the developer should submit a Notice of Termination to terminate his NPDES permit. In both of these cases, the party, which purchases the development or block within the development, should obtain a copy of the original developer's SWP3 and continue to implement it within their area(s), or develop their own SWP3, as appropriate. If you have questions regarding permit transfers or Individual Lot NOIs, contact Ohio EPA.

Special Considerations Regarding Redevelopment Sites

Prior land use of a site can pose special challenges for the SWP3 designer. 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, which may exist on redevelopment sites. Discharging runoff from these areas is typically not permitted. So, the SWP3 must find ways to keep the runoff on site or provide treatment. In most cases, additional permits must be obtained from the Ohio EPA, the Ohio Department of Natural Resources or the US Army Corps of Engineers to disturb soils within such areas. Ohio EPA may even require an individual NPDES permit for stormwater discharges from the site. When doing a redevelopment, be sure to contact these agencies to determine potential concerns. Due to these concerns, the time for development planning may be significantly longer for a redevelopment project.

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 not only the new system, but the old system until it is no longer functional. Although redevelopment sites may pose special environmental problems, there are many benefits to redeveloping a property, least of which is 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, an essential strategy to high quality water resources is limiting new impervious areas and protecting natural stream corridors. Redevelopment of existing urban areas is environmentally preferable to continually expanding the urban fringe by developing our farm fields and outlying communities.

Because valuable land has sat idle due to fears of liability and cleanup costs associated with industrial redevelopment sites, Ohio EPA has developed the Voluntary Action Program (VAP). The VAP program attempts to remove the environmental and legal barriers that have stalled redevelopment and reuse of contaminated properties. The VAP program allows property owners, lenders and developers to investigate and clean up contaminated properties without direct oversight from Ohio EPA. As long as a property is cleaned up in accordance with the rules set forth in the VAP program, the Director of Ohio EPA will issue a covenant not to sue, which releases the owner from State civil liability, thus making the property more attractive for development. For more details concerning the VAP program, contact Ohio EPA.

Small MS4 Program

Requirements within the small MS4 program also affect the construction and development industry. Under Phase II, all publicly-operated MS4s located within urbanized areas (UA) were required to apply for NPDES permit coverage by March 10, 2003. The term MS4 does not refer solely to municipal storm sewer systems, but rather has broader applications. It not only includes local jurisdictions such as cities and townships, but includes state Departments of Transportation, universities, local sewer districts, hospitals, military bases and prisons. According to Title 40 of the code of federal regulations Part 122 Section26 (b)(8), an MS4 means:

> *"A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) that are*
>
> *(a) Owned and operated by a State, city, town, borough, county, parish, district, association, or other public body (created pursuant to State law) including special districts under State law such as sewer districts, flood control districts, or drainage districts, or similar entity, or a designated and approved management agency under section 208 of the Clean Water Act that discharges into the waters of the United States,*
>
> *(b) Designed and used for collecting or conveying stormwater,*
>
> *(c) Which is not a combined sewer, and*
>
> *(d) Which is not part of a Publicly Owned Treatment Works, i.e., part of the sanitary sewer system."*

Streams or other naturally occurring drainage channels are <u>not</u> typically considered to be part of the MS4. If a community has both combined and separate sewer areas, these regulations apply only to the separate sewer systems. For those communities with combined sewer areas, it each storm sewer should be assessed on a case-by-case basis. There are instances of separate storm sewer systems within "combined sewer areas". If a storm sewer or ditch discharges directly to a water of the state under normal operating conditions, it is a separate storm sewer and must be regulated under this program.

The MS4 program only applies to entities, which lie with an Urbanized Area (UA). The US Census Bureau defines a UA as:

> *"A land area comprising one or more places - central place(s) - and the adjacent densely settled surrounding area - urban fringe - that together have a residential population of at least 50,000 and an overall population density of at least 1,000 people per square mile."*

The boundaries of the UA for purposes of the small MS4 Stormwater NPDES Permit program were determined by the results of the 2000 Census. Maps depicting the boundaries of the UA can be obtained from Ohio EPA or downloaded from the following USEPA website:

http://cfpub.epa.gov/npdes/stormwater/urbanmapresult.cfm?state=OH

Ohio EPA provides lists of jurisdictions in Ohio, which lie in whole or in part within an UA as determined by the 2000 Census. It is important to note that the boundaries of the UA change with each decennial census. However, once a municipality or township is named within a UA, it remains regulated under the NPDES stormwater program even if future censuses remove it from the UA boundary.

The NPDES permit issued to small MS4s includes two requirements, which directly affect the construction and development industry. Affected jurisdictions are required to develop a local construction site runoff control program as well as develop a post-construction stormwater management program.

MS4 Construction Site Runoff Control

Jurisdictions within Urbanized Areas are required to develop a local sediment and erosion control program that includes the following five elements:

(1) Pass an ordinance or other regulatory mechanism requiring the implementation of proper sediment and erosion controls and proper controls for other wastes on construction sites that disturb 1 or more acre of land in the larger common plan of development or sale, i.e., require stormwater Best Management Practices (BMPs) on construction sites. This includes redevelopment sites where 1 or more acres will be disturbed by construction activity.

(2) Have a procedure in place for pre-construction review of the Stormwater Pollution Prevention Plan (SWP3), being sure to consider potential water quality impacts that the construction project may have on the receiving stream(s).

(3) Site inspection during construction to ensure compliance with the SWP3.

(4) Have sanctions to ensure compliance (such as stop work orders, monetary fines, bonding requirements or permit denial).

(5) Establish procedures for the receipt and consideration of information submitted by the public.

In most cases, the requirements of the local program will mirror the requirements of the NPDES permit issued by Ohio EPA. Under Phase II regulations, Ohio EPA will review local programs and can certify them as a "qualifying local program". This means that if a construction site is located in a community covered by a qualifying local program, then the construction site operator's compliance with the local program constitutes compliance with the NPDES permit. Check with Ohio EPA to determine whether a particular local program has been certified. However, the operator will still be required to obtain coverage under an NPDES permit issued by Ohio EPA.

Be aware that in some cases, the qualifying local program will have more stringent requirements than the baseline requirements set forth in the NPDES permit. As such, operators should contact the municipality or township to determine local requirements regarding erosion and sediment control on construction sites.

Post-Construction Stormwater Management Program

In addition to a local program for construction site runoff, jurisdictions within Urban Areas must also develop a program for long-term stormwater management from new developments or redevelopment sites that disturb 1 or more acres. This program is referred to as post-construction stormwater management because it addresses the stormwater discharges, which occur after the site is fully developed. The local program must:

- Develop and implement strategies, which include a combination of structural and/or non-structural BMPs.
- Have an ordinance or other regulatory mechanism requiring the implementation of post-construction runoff controls to the extent allowable under State or local law.
- Ensure adequate long-term operation and maintenance of these controls

The suite of post-construction BMPs implemented on any given site must be capable of not only reducing or removing the pollutants found in urban runoff, but also reducing the impacts caused by discharging increased quantities of runoff when impervious surfaces are created. Ohio EPA requires post-construction stormwater discharges to be protective of stream channel and floodplain morphology and hydrology but does not impose specific design standards for flood control. The local government usually determines flood control requirements. As such, each community must be consulted individually to determine local requirements.

NPDES permits require structural post-construction practices for all large construction activities. Structural BMPs must capture and treat the water quality volume as described in the Ohio EPA General Stormwater NPDES Permit for Construction Activities, and in the structural practices section of chapter 2 of this manual. The latter contains specifications for non-proprietary structural post-construction practices, which have been shown to improve the quality of stormwater runoff. The design of these BMPs has been reviewed to assure that they comply with the requirements of the current NPDES permit.

As noted in the post-construction BMP section of this manual, sound planning procedures are an integral part of post-construction stormwater management. Guiding growth away from environmentally-sensitive areas or adopting zoning or building regulations that allow developers to minimize the amount of impervious surfaces created by development will go a long way toward meeting the objectives of this program. Still stormwater practices like those contained in Chapter 2 of this manual will be a required part of this program. Because requirements will vary from jurisdiction to jurisdiction, if you are developing a site within an urbanized area, contact the local jurisdiction to determine the specific requirements of the local stormwater management program.

Appendix 3: Development Permitting and Approval Process in Ohio

The following is an example of how development and permitting occur in many communities in Ohio. It should be noted that development processes vary substantially depending on the local jurisdiction and local requirements. Sponsors of development projects need to contact the local jurisdiction to ascertain the approvals that will apply to their project.

Step 1. Conceptual Phase

During the conceptual phase of a development, a developer or landowner should investigate the physical characteristics of the property in question, including soil suitability, site drainage, potential wetlands, topography, condition of and regulations covering existing water bodies, and previous/current land use issues. Some of this information may be available at the local Soil and Water Conservation District Office. Sewer and water service must be considered at this time, whether it is provided by extending sewer and water service or providing on-site septic and wells. With this information, the developer will be better able to consider potential site limitations and local, state or federal regulations that will be encountered as well as additional economic considerations. Investing in soil borings or wetland delineation at this stage may save a developer time and money in the long run.

The local zoning code, obtained from the county, township or municipal zoning office, should also be reviewed. If the current zoning of the property is not conducive to the type of development desired, the developer must reconsider the type of development or apply for a rezoning of the property. If the desired zoning does not exist, it would be worthwhile to work with the municipality or township and county to develop the necessary zoning language and have it adopted before initiating the project. When creating a subdivision in the unincorporated areas, the developer must comply with the county's subdivision regulations, obtained through the County or Rural Planning Agency. Municipalities will have their own subdivision regulations and zoning codes at the local zoning departments.

Step 2. Preliminary Plan

Once property information has been compiled, a Preliminary Plan is created for the development. The Preliminary Plan is a drawing of a proposed subdivision or project showing the division of parcels and the location of generalized improvements such as streets, stormwater, and waste water treatment. The preliminary plan allows a public review of the proposed project and which, if approved, permits proceeding with preparation of more specific improvement drawings and a final plat. City or county planning agencies insure that preliminary plans are in compliance with subdivision or other applicable regulations for the development of land. At the preliminary planning stage, planning departments often request comments from the township/city, county, state, and federal agencies, neighboring landowners, and other interested parties. Prior to preliminary plan approval by the planning commission or planning authority, conceptual approvals will be necessary from the township, other local agencies including the provider(s) of sewer and water (city, county or private entity), and/or the health department for septic and well water permitting information. The city or county engineering authority will review and comment on the site layout, road design, and stormwater management issues, while the local Soil and Water Conservation District office often addresses soil concerns, erosion and sediment control and water quality needs of the proposed project.

The existence of streams and wetlands should be noted on preliminary plans, having been explored prior to detailed engineering studies for the development. Two agencies, U.S. Army Corps of Engineers and the Ohio Environmental Protection Agency have jurisdiction over stream and wetland impacts in Ohio. Additional information is given in Appendix _ Overview of Stream/Wetland Regulations. If site characteristics, soils maps or other resource maps indicate the potential for wetlands to exist, a qualified wetland consultant should be retained to perform a wetland delineation and to follow the necessary permitting requirements. Note: Note in addition to US Army Corps of Engineer or Ohio EPA permits other local requirements may apply such as floodplains, or stream setbacks.

Step 3. Improvement Drawing Phase

After the preliminary plan is approved by the local planning commission, the actual design or Improvement Drawing phase begins. At this stage, the developer's engineer provides detailed designs for infrastructure such as roadways, water supply, wastewater systems and storm drainage including a detailed analysis of stormwater quality and quantity. It is generally at this time that the erosion and sediment control plans or the Stormwater Pollution Prevention Plan (SWP3 or SWPPP) is created. This plan outlines steps and practices to minimize damage to water resources from both construction activities (primarily sediment) and from impacts of the new landuse and stormwater runoff. It contains erosion and sediment control practices applied during construction, and also specifies post-construction or permanent practices aimed at protecting the overall water quality of streams and water resources of the site and downstream area. Although the SWP3 is generally created at this point, it is important to remember that overall site planning and the design principles mentioned in the other chapters are integral components of a good stormwater pollution prevention plan (SWP3). Of course, the improvement drawings incorporate both stormwater pollution prevention aspects and traditional stormwater management requirements of the local government.

The SWP3 portion of improvement drawings are required by the Ohio Environmental Protection Agency (Ohio EPA) under the General Stormwater National Pollutant Discharge Elimination System (NPDES) Permit for Construction Sites. Appendix _ provides more information about NPDES permit regulations for construction activities. This permit requires the owner or developer to submit a notice of intent (NOI) to the Ohio EPA prior to the start of construction once an adequate plan is developed. By submitting an NOI, the developer certifies than an SWP3 has been developed. The SWP3 review and in some cases, approval, is often done by the local Soil and Water Conservation District or other reviewing agency in the majority of Ohio's urbanizing counties. The Ohio EPA reserves the right to review the SWP3 and to request revisions if necessary even if review is performed by another entity. In addition to Ohio EPA's requirements, local units of government may have their own requirements, which may be more restrictive. For examples of a local erosion and sediment control or stormwater ordinance contact the Ohio Department of Natural Resources or your local Soil and Water Conservation District Office.

Step 4. Final Plat and Construction

Once the Improvement Drawings have been reviewed and approved by the city or county engineering authority and the SWPPP portion has been reviewed and approved by the Soil and Water Conservation District or Ohio EPA, the developer will seek bids from local contractors. A pre-construction meeting should be held with the county or city engineer, sanitary engineer, developer, developer's engineer, contractor, township or city zoning inspector and road superintendent, Soil and Water Conservation District, sewer and water provider, and other interested parties, prior to the start of construction, to discuss the construction plans and specifications for the project and determine site contacts and inspection schedules.

Within seven days of the start of clearing and grubbing, the necessary Best Management Practices for erosion and sediment control should be installed. Regular inspections for compliance with the SWP3 and the NPDES General Permit may be performed by the Soil and Water Conservation District, Ohio EPA, the contractor's representative and by the local inspection authority if one exists.

The Final Plat provides a final drawing of the project including all lot, street, easement, and complete survey information. Once the final plat for the development is approved by the county planning commission or local unit of government, it is recorded and the developer can then sell lots. After all of the improvements for the project have been installed, the developer's last requirement is to complete stabilization of the site. All bare areas should be stabilized prior to selling lots to the builders or homebuyers. If the developer does not choose to remain responsible for the erosion and sediment control on the individual building lots, he can work with the builders to obtain Individual Lot Notices of Intent (NOI) and transfer the responsibility to them.

Regulatory Review and Contact Information

Level of Government	Agency	Oversees
Federal	Army Corps of Engineers (ACOE) www.usace.army.mil	• Wetlands* • Stream channel alteration
State	Ohio Environmental Protection Agency (OEPA) www.epa.state.oh.us	• National Pollutant Discharge Elimination System permit (NPDES) Notice of Intent (NOI) – application for NPDES permit coverage Stormwater Pollution Prevention Plan (SWP3) • Total Maximum Daily Load (TMDL) • Wetlands and Isolated Wetlands • Permits to Install (PTIs) for sanitary sewer extensions or commercial and industrial sewage disposal systems • Redevelopment of sites with prior industrial land use may require the following permits: > Rule 13 (Landfills) > VAP Program (Contaminated Soils) > Phase I and II Assessments > No Further Action Letter > Covenant Not to Sue
	Ohio Department of Natural Resources ODNR) www.dnr.state.oh.us	• Existing dams (Ohio Dam Law)
County	Health Department	• Septic systems for residential developments • Drinking water wells for residential developments
	Sanitary Engineer	• Centralized sewer and water
	County Engineer/Stormwater Manage-ment	• Stormwater management • Road specifications (site distance)
	Soil and Water Conservation District (SWCD)	• Soils information • Stormwater Pollution Prevention Plan (SWP3) (Where required under local ordinances. The SWP3 is a requirement of the Ohio EPA.)
	Planning Agency	• Conformance to county subdivision regulations; county resolutions
Local	Municiplity or Township Planning Office	• Local zoning code • Ordinances
	City Engineer/Stormwater Management	• Sewer and water connections • Erosion and sediment controls • Construction and Stormwater management plans • Improvement plans

* Indicates primary contact agency

General components for each stage of development planning

1. Concept plan

• Physical site assessment
• Review current zoning
• Investigate
  > Previous land uses
  > Existing structures (ponds, channels)
  > Wetlands
  > Well suitability
  > Soils suitability for building/ septic
  > Available centralized utilities

2. Preliminary Plan

• Physical layout with lots/ structures
• Road layout with site distances
• Soils analysis
• Wetlands delineation
• Confirmation of utilities availability

3. Improvements Plan

• Pre-construction meeting
• Stormwater design
• Water quality calculations
• SWPPP design (Stormwater Pollution Prevention Plan)
• Utility layout connections

4. Final Plat

• Site conforms to zoning
• Lots recorded and can be sold

Appendix 4: Overview of Stream/Wetland Regulations

According to the federal Clean Water Act, anyone who wishes to discharge dredged or fill material into the waters of the U.S., must obtain a Section 404 permit from the U.S. Army Corps of Engineers (Corps) and a Section 401 Water Quality Certification (WQC) from the state. The Corps will also require a Section 10 permit if the fill is located in a navigable water.

Section 404 Permits

Section 404 of the Clean Water Act requires approval prior to discharging dredged or fill material into the waters of the United States. Typical activities requiring Section 404 permits are:

- Depositing of fill or dredged material in waters of the U.S. or adjacent wetlands.
- Site development fill for residential, commercial, or recreational developments.
- Construction of revetments, groins, breakwaters, levees, dams, dikes, and weirs.
- Placement of riprap and road fills.

Waters of the United States

Waters of the United States includes essentially all surface waters such as all navigable waters and their tributaries, all interstate waters and their tributaries, all wetlands adjacent to these waters, and all impoundments of these waters.

"Wetlands" are areas characterized by growth of wetland vegetation (bulrush, cattails, rushes, sedges, willows, pickleweed) where the soil is saturated during a portion of the growing season or the surface is flooded during some part of most years. Wetlands generally include swamps, marshes, bogs, and similar areas.

The landward regulatory limit for non-tidal waters (in the absence of adjacent wetlands) is the *ordinary high water mark*. The ordinary high water mark is the line on the shores established by the fluctuations of water and indicated by physical characteristics such as:

- a clear natural line impressed on the bank;
- shelving;
- changes in the character of the soil;
- destruction of terrestrial vegetation;
- the presence of litter and debris;
- or other appropriate means that consider the characteristics of the surrounding areas.

Navigable Waters

Navigable waters are defined as waters that have been used in the past, are now used, or are susceptible to use as a means to transport interstate or foreign commerce up to the head of navigation. Section 10 and/or Section 404 permits are required for construction activities in these waters. A complete list is available from the Army Corps of Engineers District Office.

Section 401 Water Quality Certification

The 401 Water Quality Certification (WQC) is required from Ohio EPA prior to the Corps approval of a Section 404 permit. Essentially these permitting processes work in tandem and include much of the same information. The 401 WQC requires an anti-degradation analysis investigating three alternatives: preferred alternative, minimum degradation alternative, and non-degradation alternative. The preferred alternative would include impacts that allow the applicant to develop the property in a preferred development plan. The minimum degradation alternative must minimize the impacts to water resources while still allowing the project to be constructed in an economically viable fashion. The non-degradation alternative must propose a site development plan, which includes zero water quality impacts to surface waters of the state. 401 WQC will be reviewed with varying levels of scrutiny based on the amount of impacts and quality of water resources. For example, a public need must be demonstrated to allow for impacts to category 3 wetlands, but this review is not necessary for impacts to category 1 or 2 wetlands. Fees are required at the time of application and for review of Ohio 401 Water Quality Certification applications.

Generally there are two types of 404 permits applicable to most entities in the State of Ohio, depending on the amount of linear feet of stream, linear feet of shoreline or acres of wetland proposed to be impacted. The types of permits include Individual Permits and Nationwide Permits. Additionally the Ohio Department of Transportation has been issued a Regional General Permits for for transportation projects meeting prescribed conditions.

Individual Permits

Individual permits are issued following a full public interest review of an individual application for a Department of the Army permit. A public notice is distributed to all known interested persons. After evaluating all comments and information received, final decision on the application is made.

The permit decision is generally based on the outcome of a public interest balancing process where the benefits of the project are balanced against the detriments. A permit will be granted unless the proposal is found to be contrary to the public interest. Processing time may take at least 120 days, although the Army Corps of Engineers is allowed up to 1 year to process permits.

Individual permits will require an individual 401 WQC from the Ohio EPA including a full antidegradation review.

Nationwide Permits

A nationwide permit is a form of general permit, which authorizes a category of activities throughout the nation. Nationwide Permits are for certain types of projects that are similar in nature and cause minimal degradation to waters of the state. These permits substantially expedite the permitting process. These permits are valid only if the conditions applicable to the permits are met. If the conditions cannot be met, an individual permit will be required.

Ohio EPA has pre-granted Section 401 Water Quality Certifications to Nationwide Permits with general and specific conditions. To determine if your project qualifies for Nationwide Permit coverage, or requires an individual Section 401 WQC from Ohio EPA, applicants should contact the Corps first to discuss the project.

Isolated Wetland Permits

In January 2001, the United States Supreme Court Decision in the case of Solid Waste Agency of

Page updated 5-4-12

Northern Cook County (SWANCC) v. United States Army Corps of Engineers stated that the Corps did not have authority to regulate isolated wetlands under Section 404 of the Clean Water Act. Prior to that ruling, the Corps regulated activities in all streams and wetlands through the issuance of 404 Permits.

As a result of this decision, the Ohio EPA adopted emergency rules in April of 2001 to establish a state-permitting program, but these rules were effective for only ninety days. On July 17, 2001, Governor Bob Taft signed House Bill 231 into law. The bill establishes a permanent permitting process for isolated wetlands. The Army Corps of Engineers has maintained the authority to determine whether a wetland is isolated. If the determination by the Corps is that the wetland is isolated, applicants must contact the Ohio EPA to determine the correct level of Isolated Wetland Permit. More information can be found on the Ohio EPA web site.

Pre-Application Consultation

Applicants are encouraged to contact the Corps of Engineers and the Ohio EPA for proposed work in waters of the state. By discussing all information prior to application submittal, the application will be processed more efficiently. If an applicant is unsure if an application is required, the Corps will provide an official determination as to the need for a Department of the Army permit upon request.

Contacts for Ohio EPA and Army Corps of Engineers

Ohio EPA, 401 Water Quality Certifications

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Columbus, Ohio 43216-1049
(614) 644-2013
Tom.Harcarik@epa.state.oh.us
www.epa.state.oh.us/dsw/401/401section.html

For Questions about the Ohio Rapid Assessment Method, contact Brian Gara at the above address or at (614) 836-8787, Brian.Gara@epa.state.oh.us

U.S. Army Corps of Engineers, Section 404 Permits

Buffalo District

1776 Niagara Street
Buffalo, NY 14207-3199
FAX (716) 879-4310
http://www.lrb.usace.army.mil/orgs/reg/index.htm

Louisville District

Attention: Regulatory Branch, OP-F
P.O. Box 59
Louisville, KY 40201-0059
Phone: (502) 315-6733
http://www.lrl.usace.army.mil/

Huntington District

502 Eighth Street
Huntington, WV 25701
(604) 529-5210
http://www.lrh.usace.army.mil/or/permits/

Pittsburgh District

William S. Moorhead Federal Building
1000 Liberty Avenue
Pittsburgh, PA 15222
http://www.lrp.usace.army.mil/or/or-f/permits.htm

Page updated 5-4-12

Definitions Associated with 404/401 and Isolated Wetland Permits

Isolated Wetlands – per OAC 3745-1-50

"Hydrologically isolated wetlands" means those wetlands which;

(1) Have no surface water connection to a surface water of the state;

(2) Are outside of, and not contiguous to, any one hundred year "floodplain" as that term is defined in this rule; and

(3) Have no contiguous hydric soil between the wetland and any surface water of the state.

Ordinary High Water Mark

Landward regulatory limit for non-tidal waters (in the absence of adjacent wetlands). Line on the shores or river banks established by the fluctuations of water and indicated by physical characteristics such as:

- a clear natural line impressed on the bank;
- shelving;
- changes in the character of the soil;
- destruction of terrestrial vegetation;
- the presence of litter and debris;
- or other appropriate means that consider the characteristics of the surrounding areas.

Navigable Waters

Waters that have been used in the past, are now used, or are susceptible to use as a means to transport interstate or foreign commerce up to the head of navigation. Section 10 and/or Section 404 permits are required for construction activities in these waters. A complete list is available in the Corps District Offices.

Ohio Rapid Assessment Method (ORAM)

Method which allows an applicant to assess the quality of the wetland without completing detailed vegetative or hydrologic analyses. The outcome of applying this method is the categorization of wetlands as either Category 1, 2 or 3. The Ohio EPA reviews categorization of wetlands. The current manual is ORAM Version 5.0.

Waters of the State

"Surface waters of the state" or "water bodies" mean all streams, lakes, reservoirs, ponds, marshes, wetlands or other waterways which are situated wholly or partially within the boundaries of the state, except those private waters which do not combine or effect a junction with natural surface or underground waters. Waters defined as sewerage system, treatment works or disposal system in section 6111.01 of the Revised Code are not included.

Wetlands – Effective 12/30/2002, Per OAC 3745-1-02

"Wetlands" means those areas that are inundated or saturated by surface or ground water at a frequency and duration that are sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. "Wetlands" includes swamps, marshes, bogs, and similar areas that are delineated in accordance with the 1987 United States Army Corps of Engineers wetland delineation manual and any other procedures and requirements adopted by the United States army corps of engineers for delineating wetlands.

Page updated 5-4-12

Wetland Categories – Per, OAC 3745-1-54(C)

Category 1 Wetlands

a) support minimal wildlife habitat, and minimal hydrological and recreational functions as determined by an appropriate wetland evaluation methodology acceptable to the director. Wetlands assigned to category 1 do not provide critical habitat for threatened or endangered species or contain rare, threatened or endangered species.

b) Wetlands assigned to category 1 may be typified by some or all of the following characteristics: hydrologic isolation, low species diversity, a predominance of non-native species (greater than fifty per cent areal cover for vegetative species), no significant habitat or wildlife use, and limited potential to achieve beneficial wetland functions.

c) may include, but are not limited to, wetlands that are acidic ponds created or excavated on mined lands without a connection to other surface waters throughout the year and that have little or no vegetation and wetlands that are hydrologically isolated and comprised of vegetation that is dominated (greater than eighty per cent areal cover) by species including, but not limited to: *Lythrum salicaria; Phalaris arundinacea;* and *Phragmites australis.*

Category 2 Wetlands

a) support moderate wildlife habitat, or hydrological or recreational functions as determined by an appropriate wetland evaluation methodology acceptable to the director or his authorized representative.

b) may include, but are not limited to: wetlands dominated by native species but generally without the presence of, or habitat for, rare, threatened or endangered species; and wetlands which are degraded but have a reasonable potential for reestablishing lost wetland functions.

Category 3 Wetlands

a) support superior habitat, or hydrological or recreational functions as determined by an appropriate wetland evaluation methodology acceptable to the director or his authorized representative.

b) may be typified by some or all of the following characteristics: high levels of diversity, a high proportion of native species, or high functional values.

c) may include, but are not limited to: wetlands which contain or provide habitat for threatened or endangered species; high quality forested wetlands, including old growth forested wetlands, and mature forested riparian wetlands; vernal pools; and wetlands which are scarce regionally and/or statewide including, but not limited to, bogs and fens.

Wetland Delineation

Process utilized to determine the areal extent and boundaries of a jurisdictional wetland. Currently, the 1987 U.S. Army Corps of Engineers Manual details the procedures for performing a wetland delineation. The results of a wetland delineation are reviewed by the Army Corps of Engineers.

Appendix 5: Resource Agencies

Technical Standards, Training and Informational Materials

Ohio Department of Natural Resources (614) 265-6610
Division of Soil and Water Conservation
2045 Morse Road, Bldg B-3
Columbus, Ohio 43224-6693
http://soilandwater.ohiodnr.gov/

Technical Resources

Natural Resources Conservation Service (614) 255-2500
U.S. Department of Agriculture-NRCS
200 North High Street, Room 522
Columbus, Ohio 43215-2478
www.oh.nrcs.usda.gov

NPDES Stormwater Permits and Stream/Wetland 401 Water Quality Certification

Ohio EPA, Division of Surface Water (614) 644-2001

STREET ADDRESS & SHIPPING
Lazarus Government Center
122 South Front Street
Columbus OH 43215

MAILING ADDRESS
Lazarus Government Center
P.O. Box 1049
Columbus OH 43216-1049

Central Office
Construction General Permits(614) 752-0782
Municipal NPDES Phase I Permits(614) 728-3392
Municipal NPDES Phase II Permits(614) 728-1793
Industrial NPDES Permits.(614) 644-2259
http://www.epa.state.oh.us/dsw/storm/index.aspx

Ohio EPA 401 Water Quality Certification(614) 644-2013
http://epa.ohio.gov/dsw/401/permitting.aspx

NPDES Stormwater Permits – Field Personnel
Ohio EPA District Offices:
Northeast...........................(330) 963-1145
Northwest..........................(419) 373-3009
Southeast...........................(614) 380-5430
Southwest..........................(513) 285-6357
Central...............................(614) 728-3844

Page updated on 11-6-14

Wetland and Stream Modification Regulations

Army Corps of Engineers:
Huntington District--Most of Ohio, Central and Southern .... (304) 529-5210
Buffalo--Northern Ohio, Lake Erie Watershed (716) 879-4330
Louisville--Southwest Ohio (502) 582-5607
Pittsburgh--Eastern Ohio bordering Pennsylvania (412) 644-6874

Loans & Financial Assistance for Land Use Planning, Stream Protection and Mitigation Projects

Ohio EPA, Division of Environmental and Financial Assistance.......... (614) 644-2832

STREET ADDRESS & SHIPPING	MAILING ADDRESS
Lazarus Government Center	Lazarus Government Center
122 South Front Street	P.O. Box 1049
Columbus OH 43215	Columbus OH 43216-1049

http://epa.ohio.gov/defa/EnvironmentalandFinancialAssistance.aspx

Flood Plain Regulations – Dam Safety Permits

Ohio Department of Natural Resources, Division of Water .... (614) 265-6717

Floodplain Regulation:
www2.ohiodnr.com/soilwater/water-use-planning/floodplain-management

Dam Safety:
www2.ohiodnr.com/soilwater/safety/dam-safety

Page updated on 11-6-14

SWCD Addresses and Telephone Numbers: Information on County and Municipal Stormwater Programs and Development Regulations, Technical Assistance, Plan Review and Site Inspection, and Soil Surveys. Most recently updated contact information available at http://soilandwater.ohiodnr.gov.

ADAMS (937) 544-1010
215 N. Cross St., Suite 106
West Union, OH 45693-

ALLEN (419) 223-0040
1601 E. Fourth St.
Lima, OH 45804

ASHLAND (419) 281-7645
1763 State Route 60
Ashland, OH 44805

ASHTABULA (440) 576-4946
39 Wall Street
Jefferson, OH 44047-1137

ATHENS (740) 797-9686
69 South Plains Road, Suite 107
The Plains, OH 45780-

AUGLAIZE (419) 738-4016
110 Industrial Drive, Suite G
Wapakoneta, OH 45895-9231

BELMONT (740) 526-0027
101 N. Market St., Suite D
St. Clairsville, OH 43950

BROWN (937) 378-4424
706 South Main Street
Georgetown, OH 45121

BUTLER (513) 887-3720
1802 Princeton Road
Hamilton, OH 45011

CARROLL (330) 627-9852
613 North High Street
Carrollton, OH 44615

CHAMPAIGN (937) 484-1507
1512 South US Hwy. 68, Suite E-100
Urbana, OH 43078-

CLARK (937) 521-3880
Springview Government Center
3130 E. Main St.
Springfield, OH 45505

CLERMONT (513) 732-7075
P.O. Box 549, 1000 Locust Street
Owensville, OH 45160-0549

CLINTON (937) 382-2461
111 South Nelson Avenue, Suite 5
Wilmington, OH 45177

COLUMBIANA (330) 332-8732
1834-B South Lincoln Avenue
Salem, OH 44460

COSHOCTON (740) 622-8087
724 South Seventh St,
Coshocton, OH 43812

CRAWFORD (419) 562-8280
3111 State Route 98
Bucyrus, OH 44820-9601

CUYAHOGA (216) 524-6580
6100 West Canal Road
Valley View, OH 44125

DARKE (937) 548-2410 Ext. 3
1117 South Towne Court
Greenville, OH 45331

DEFIANCE (419) 782-8751
06879 Evansport Road, Suite C
Defiance, OH 43512-

DELAWARE (740) 368-1921
557 A Sunbury Road
Delaware, OH 43015-8656

ERIE (419) 626-5211
2900 Columbus Avenue Room 131
Sandusky, OH 44870-5554

FAIRFIELD (740) 653-8154
831 College Avenue, Suite B
Lancaster, OH 43130-

FAYETTE (740) 636-0279
1415 US HWY 22 SW, Suite 500
Washington, CH, OH 43160-8654

FRANKLIN (614) 486-9613
1404 Goodale Boulevard, Suite 100.
Columbus, OH 43212

FULTON (419) 337-9217
8770 State Route 108, Suite B
Wauseon, OH 43567

GALLIA (740) 446-6173
111 Jackson Pike, Suite 1569
Gallipolis, OH 45631-1569

GEAUGA (440) 834-1122
PO Box 410, 14269 Claridon-Troy Rd.
Burton, OH 44021

GREENE (937) 372-4478
1363 Burnett Drive
Xenia, OH 45385-5681

GUERNSEY (740) 432-5624
9711 East Pike Rd, Rm 102
Cambridge, OH 43725

HAMILTON (513) 772-7645
22 Triangle Park Drive
Cincinnati, OH 45246-3411

HANCOCK (419) 422-6569
7868 Co. Rd. 140, Suite E
Findlay, OH 45840-

HARDIN (419) 673-0456
12751 SR 309W
Kenton, OH 43326-9474

HARRISON (740) 942-8837
538 North Main Street, Suite I
Cadiz, OH 43907

HENRY (419) 592-2926
2260 North Scott Street
Napoleon, OH 43545

HIGHLAND (937) 393-1922
514 Harry Sauner Road, Suite 2
Hillsboro, OH 45133

HOCKING (740) 385-3016
148 North Homer Avenue
Logan, OH 43138-1730

HOLMES (330) 674-2811
62 West Clinton Street
Millersburg, OH 44654-1148

HURON (419) 668-4113
8 Fair Road
Norwalk, OH 44857

JACKSON (740) 286-5208
2026 Fairgreens Road
Jackson, OH 45640-9057

JEFFERSON (740) 264-9790
587 Bantam Ridge Road Ste A
Wintersville, OH 43953

KNOX (740) 393-6724
160 Columbus Road
Mount Vernon, OH 43050

Page updated on 11-6-14

LAKE (440) 350-2730
125 East Erie Street
Painesville, OH 44077-

LAWRENCE (740) 867-4737
5459 St. Rt. 217, PO Box 144
Willow Wood, OH 45696

LICKING (740) 670-5330
771 East Main Street, Suite 100
Newark, OH 43055-6900

LOGAN (937) 593-2946
324 County Road 11
Bellefontaine, OH 43311-

LORAIN (440) 326-5800
42110 Russia Road
Elyria, OH 44035

LUCAS (419) 893-1966
130-A West Dudley Street
Maumee, OH 43537-

MADISON (740) 852-4004
831 U.S. HWY 42 NE
London, OH 43140

MAHONING (330) 740-7995
850 Industrial Road
Youngstown, OH 44509

MARION (740) 387-1314
1100 East Center Street
Marion, OH 43302-

MEDINA (330) 722-2628
6090 Wedgewood Road
Medina, OH 44256

MEIGS (740) 992-4282
33101 Hiland Road
Pomeroy, OH 45769

MERCER (419) 586-3289
220 West Livingston St, Suite 1
Celina, OH 45822

MIAMI (937) 335-7645
1330 N County Road 25A, Suite C
Troy, OH 45373

MONROE (740) 472-0833
117 N. Main Street, 3rd Floor
Woodsfield, OH 43793

MONTGOMERY (937) 854-7645
10025 Amity Road
Brookville, OH 45309-9399

MORGAN (740) 962-4234
167 S. Kennebec Ave.
McConnelsville, OH 43756

MORROW (419) 946-7923
871 West Marion Road, Suite 203
Mt. Gilead, OH 43338-

MUSKINGUM (740) 454-2027
225 Underwood Street, Suite 100
Zanesville, OH 43701-

NOBLE (740) 732-4318
18506 SR 78 East
Caldwell, OH 43724

OTTAWA (419) 898-1595
240 West Lake Street, Unit B
Oak Harbor, OH 43449

PAULDING (419) 399-4771
503 Fairground Drive
Paulding, OH 45879

PERRY (740) 743-1325
109-A East Gay Street, P.O. Box 337
Somerset, OH 43783

PICKAWAY (740) 477-1693
110 Island Road, Suite D
Circleville, OH 43113-9056

PIKE (740) 947-5353
11752 SR 104
Waverly, OH 45690

PORTAGE (330) 297-7633
6970 State Route 88
Ravenna, OH 44266

PREBLE (937) 456-5159
1651 North Barron Street
Eaton, OH 45320-1021

PUTNAM (419) 523-5159
1206 E. Second St.
Ottawa, OH 45875

RICHLAND (419) 747-8686
1495 West Longview Ave, Suite 205B
Mansfield, OH 44906-1872

ROSS (740) 772-4110
475 Western Avenue, Suite H
Chillicothe, OH 45601-

SANDUSKY (419) 334-6324
2000 Countryside Drive, Suite A
Fremont, OH 43420-

SCIOTO (740) 259-9231
12167A State Route 104
Lucasville, OH 45648-8330

SENECA (419) 447-7073
3140 South St. Rt. 100, Suite D
Tiffin, OH 44883-

SHELBY (937) 492-6520
822 Fair Road
Sidney, OH 45365-

STARK (330) 830-7700
2650 Richville Drive SE, Suite 103
Massillon, OH 44646

SUMMIT (330) 929-2871
2525 State Rd.
Cuyahoga Falls, OH 44223

TRUMBULL (330) 637-2056
520 West Main Street, Suite 3
Cortland, OH 44410-1455

TUSCARAWAS (330) 339-7976
2201 Progress Drive Suite B
Dover, OH 44622

UNION (937) 642-5871
18000 State Route 4, Suite B
Marysville, OH 43040

VAN WERT (419) 238-9591
1185 Professional Drive
Van Wert, OH 45891-

VINTON (740) 596-5676
31935 SR 93
McArthur, OH 45651-8766

WARREN (513) 695-1337
320 East Silver Street, Suite 300
Lebanon, OH 45036-1887

WASHINGTON (740) 373-4857
21330 St. Rt. 676, Suite E
Marietta, OH 45750-6799

WAYNE (330) 262-2836
428 West Liberty Street
Wooster, OH 44691

WILLIAMS (419) 636-9395
1120 West High Street
Bryan, OH 43506-1540

WOOD (419) 354-5517
1616 East Wooster Street, Box 32
Bowling Green, OH 43402

WYANDOT (419) 294-2312
97 Houpt Drive, Suite A
Upper Sandusky, OH 43351-9201

Appendix 6: Soils with Greatest Potential Use for Infiltration

The following is a list of Ohio soil map units that have the optimum soil characteristics for infiltration. These soils have a natural drainage class that is well drained, depths to bedrock over 100 inches and an appropriate saturated hydraulic conductivity between the depths of 20-60 inches.

Saturated hydraulic conductivity is the amount of water that would move vertically through a unit of saturated soil per unit time under hydraulic gradient, described in the National Soil Survey Handbook (http://soils.usda.gov/technical/hand¬book/contents/part618p3.html#50).

Of course, site designers must realize that soil map units are not enough information for design. For example, soil map units may have inclusions of other soils types. Some soil map units not listed here, such as the urban soil complex, are too disturbed to characterize consistently in this format. Also note that some of the following soils may have other limitations such as steep slopes and although they may receive water well, these may limit the potential of siting an infiltration practice at the particular area. Therefore on-site measures of soil and site characteristics are always recommended.

The following tables are listed by county, showing the soil map units that meet the 3 criteria for 'greatest potential use' for infiltration. If a county is not listed, that county does not have soil map units that meet all of the criteria. Assistance to identify the potential for infiltration of soils not included in this table can be obtained by contacting soil scientists with the ODNR-Division of Soil & Water Conservation or USDA-Natural Resources Conservation Service.

Adams County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
EkB	Elkinsville silt loam, 1 to 6 percent slopes	4,642	1.2
Ge	Gessie loam, frequently flooded	2,762	0.7
	Total	7,404	2.0

Allen County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
KnA	Knoxdale silt loam, 0 to 2 percent slopes, occasionally flooded	2,750	1.1
	Total	2,750	1.1

Ashland County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
WuB	Wooster-Riddles silt loams, 2 to 6 percent slopes	---	*
WuC	Wooster-Riddles silt loams, 6 to 12 percent slopes	---	*
WuD2	Wooster-Riddles silt loams, 12 to 18 percent slopes, eroded	---	*
	Total	0	0.0

* Less than 0.1 percent.

Ashtabula County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Ch	Chagrin silt loam	2,319	0.5
Sm	Steep land, loamy	6,428	1.4
	Total	8,747	1.9

Athens County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Cd	Chagrin loam, rarely flooded	2,090	0.6
Cg	Chagrin silt loam, frequently flooded	14,250	4.4
CmC	Clymer loam, 8 to 15 percent slopes	1,000	0.3
HcA	Hackers silt loam, 0 to 3 percent slopes	820	0.3
Mp	Moshannon silt loam, frequently flooded	470	0.1
PaB	Parke silt loam, 2 to 6 percent slopes	450	0.1
RcC	Richland loam, 8 to 15 percent slopes	310	*
RcD	Richland loam, 15 to 25 percent slopes	3,640	1.1
	Total	23,030	7.1

* Less than 0.1 percent.

Auglaize County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam, occasionally flooded	2,890	1.1
	Total	2,890	1.1

Belmont County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
As	Ashton silt loam, occasionally flooded	319	*
Cf	Chagrin loam, occasionally flooded	2	*
Cg	Chagrin silt loam, occasionally flooded	2,240	0.6
DuB	Duncannon-Urban land complex, 0 to 15 percent slopes	514	0.1
No	Nolin variant silt loam, occasionally flooded	1,813	0.5
Nu	Nolin variant-Urban land complex	291	*
RcC	Richland loam, 8 to 15 percent slopes	684	0.2
RcD	Richland loam, 15 to 25 percent slopes	2,658	0.8
RcE	Richland moderately stony loam, 25 to 40 percent slopes	788	0.2
RkC	Richland channery loam, 8 to 15 percent slopes	39	*
RkD	Richland channery loam, 15 to 25 percent slopes	292	*
	Total	9,640	2.8

* Less than 0.1 percent.

Brown County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
EkB	Elkinsville silt loam, 2 to 6 percent slopes	1,802	0.6
EkC2	Elkinsville silt loam, 6 to 12 percent slopes, eroded	433	0.1
Ge	Genesee silt loam, occasionally flooded	5,982	1.9
Gn	Gessie loam, frequently flooded	10	*
HyC3	Hickory clay loam, 6 to 12 percent slopes, severely eroded	6	*
Ju	Jules silt loam, frequently flooded	755	0.2
	Total	8,988	2.8

* Less than 0.1 percent.

Butler County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee loam	9,161	3.0
Go	Genesee-Urban land complex	1,727	0.6
UnA	Uniontown silt loam, 0 to 2 percent slopes	278	*
UnB	Uniontown silt loam, 2 to 6 percent slopes	612	0.2
	Total	11,778	3.9

* Less than 0.1 percent.

Carroll County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Ek	Elkinsville silt loam, rarely flooded	419	0.2
WrC	Westmoreland silt loam, 6 to 15 percent slopes	33	*
	Total	452	0.2

* Less than 0.1 percent.

Champaign County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Go	Genesee silt loam, till substratum, occasionally flooded	84	*
RuA	Rush silt loam, 0 to 2 percent slopes	97	*
WsA	Wea silt loam, 0 to 3 percent slopes	838	0.3
	Total	1,019	0.4

* Less than 0.1 percent.

Clark County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Ge	Genesee silt loam, till substratum, rarely flooded	246	*
Gn	Genesee silt loam, till substratum, occasionally flooded	1,637	0.6
Rn	Ross silt loam, occasionally flooded	2,385	0.9
RuA	Rush silt loam, 0 to 2 percent slope	1,756	0.7
	Total	6,024	2.3

* Less than 0.1 percent.

Clermont County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam	8,144	2.8
HkD2	Hickory loam, 12 to 18 percent slopes, moderately eroded	1,442	0.5
HkF2	Hickory loam, 18 to 35 percent slopes, moderately eroded	7,602	2.6
HlG3	Hickory clay loam, 25 to 50 percent slopes, severely eroded	1,423	0.5
Hu	Huntington silt loam	1,777	0.6
	Total	20,388	6.9

Clinton County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
CuC2	Crouse-Miamian silt loams, 6 to 12 percent slopes, eroded	5,146	2.0
CuD2	Crouse-Miamian silt loams, 12 to 18 percent slopes, eroded	1,044	0.4
HkD2	Hickory silt loam, 12 to 18 percent slopes, eroded	1,704	0.6
HkE2	Hickory silt loam, 18 to 25 percent slopes, eroded	523	0.2
HkF2	Hickory silt loam, 25 to 35 percent slopes, eroded	641	0.2
HnE2	Hickory-Morrisville silt loams, 18 to 25 percent slopes, eroded	119	*
MoE2	Miamian-Crouse silt loams, 18 to 25 percent slopes, eroded	770	0.3
MoF2	Miamian-Crouse silt loams, 25 to 50 percent slopes, eroded	1,363	0.5
WmA	Williamsburg silt loam, 0 to 2 percent slopes	171	*
WmB	Williamsburg silt loam, 2 to 6 percent slopes	95	*
	Total	11,576	4.4

*Less than 0.1 percent.

Columbiana County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
RhD	Richland silt loam, 15 to 25 percent slopes, stony	272	*
RhE	Richland silt loam, 25 to 40 percent slopes, stony	204	*
	Total	476	0.1

* Less than 0.1 percent.

Coshocton County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AfB	Alford silt loam 2 to 6 percent slopes	198	*
AfC2	Alford silt loam, 6 to 15 percent slopes, eroded	616	0.2
Ht	Huntington silt loam, rarely flooded	344	*
MnA	Mentor silt loam, 0 to 2 percent slopes	787	0.2
MnB	Mentor silt loam, 2 to 6 percent slopes	829	0.2
MnC	Mentor silt loam, 6 to 15 percent slopes	1,675	0.5
MnD	Mentor silt loam, 15 to 25 percent slopes	783	0.2
RcC	Richland silt loam, 6 to 15 percent slopes	229	*
RcD	Richland silt loam, 15 to 25 percent slopes	947	0.3
WeC	Wellston silt loam, 6 to 15 percent slopes	557	0.2

WhC	Westmoreland silt loam, 6 to 15 percent slopes	3,142	0.9
WhD	Westmoreland silt loam, 15 to 25 percent slopes	13,234	3.6
WhE	Westmoreland silt loam, 25 to 35 percent slopes	13,957	3.8
	Total	37,298	10.3

* Less than 0.1 percent.

Crawford County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AdB	Alexandria silt loam, 2 to 6 percent slopes	1,038	0.4
AdC2	Alexandria silt loam, 6 to 12 percent slopes, moderately eroded	2,066	0.8
AdD2	Alexandria silt loam, 12 to 18 percent slopes, moderately eroded	573	0.2
HpE	Hennepin-Alexandria silt loams, 18 to 50 percent slopes	775	0.3
	Total	4,452	1.7

* Less than 0.1 percent.

Cuyahoga County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Ch	Chagrin silt loam, occasionally flooded	4,252	1.4
GeF	Geeburg-Mentor silt loams, 25 to 70 percent slopes	5,194	1.8
	Total	9,446	3.2

Defiance County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Ge	Genesee loam, occasionally flooded	3,299	1.2
	Total	3,299	1.2

Delaware County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
MaB	Martinsville loam, 2 to 6 percent slopes	24	*
MbB	Martinsville loam, till substratum, 2 to 6 percent slopes	959	0.3
McD2	Mentor silt loam, 12 to 18 percent slopes, eroded	63	*
RoA	Rossburg silt loam, 0 to 2 percent slopes, occasionally flooded	1,464	0.5
	Total	2,510	0.9

* Less than 0.1 percent.

Erie County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
NoA	Nolin silt loam, 0 to 2 percent slopes, occasionally flooded	576	0.3
	Total	576	0.3

Fairfield County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AfB	Alford silt loam, 2 to 6 percent slopes	2,163	0.7

AfC2	Alford silt loam, 6 to 12 percent slopes, eroded	1,860	0.6
Cg	Chagrin silt loam, frequently flooded	625	0.2
Gf	Gessie silt loam, occasionally flooded	1,748	0.5
Gg	Gessie silt loam, frequently flooded	1,841	0.6
HhC2	Hickory silt loam, 6 to 12 percent slopes, eroded	810	0.2
HkE	Hickory-Germano complex, 20 to 35 percent slopes	583	0.2
HmD2	Hickory-Gilpin complex, 12 to 20 percent slopes, eroded	2,889	0.9
PkB	Pike silt loam, 2 to 6 percent slopes	432	0.1
PkC2	Pike silt loam, 6 to 12 percent slopes, eroded	559	0.2
	Total	13,510	4.2

Fayette County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam	826	0.3
Rs	Ross silt loam	1,393	0.5
	Total	2,219	0.9

Franklin County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam, occasionally flooded	2,424	0.7
Uw	Urban land-Genesee complex, occasionally flooded	1,370	0.4
	Total	3,794	1.1

Gallia County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AkB	Allegheny loam, 3 to 8 percent slopes	550	0.2
AkC	Allegheny loam, 8 to 15 percent slopes	652	0.2
AkD	Allegheny loam, 15 to 25 percent slopes	587	0.2
Cg	Chagrin silt loam, frequently flooded	6,780	2.2
Cu	Cuba silt loam, occasionally flooded	1,226	0.4
EkB	Elkinsville silt loam, 1 to 6 percent slopes	2,129	0.7
	Total	11,924	4.0

Greene County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee loam	1,831	0.7
Rs	Ross loam	3,601	1.4
RtA	Rush silt loam, 0 to 2 percent slopes	2,036	0.8
RtB	Rush silt loam, 2 to 6 percent slopes	1,932	0.7
	Total	9,400	3.5

Guernsey County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AgC	Allegheny loam, 8 to 15 percent slopes	407	0.1

MeB	Mentor silt loam, 2 to 8 percent slopes	2,595	0.8
MeC	Mentor silt loam, 8 to 15 percent slopes	1,863	0.6
MeD	Mentor silt loam, 15 to 25 percent slopes	1,567	0.5
MfB	Mentor-Urban land complex, 2 to 8 percent slopes	152	*
MgB	Mentor silt loam, 2 to 6 percent slopes	8	*
RcC	Richland channery loam, 8 to 15 percent slopes	19	*
RcD	Richland channery loam, 15 to 25 percent slopes	471	0.1
	Total	7,082	2.1

* Less than 0.1 percent.

Hamilton County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee loam, occasionally flooded	3,912	1.5
Go	Genesee-Urban land complex, occasionally flooded	1,888	0.7
Hu	Huntington silt loam, occasionally flooded	875	0.3
Ju	Jules silt loam, occasionally flooded	5,635	2.1
McA	Martinsville silt loam, 0 to 2 percent slopes	2,073	0.8
McB	Martinsville silt loam, 2 to 6 percent slopes	616	0.2
PbB2	Parke silt loam, 3 to 8 percent slopes, eroded	575	0.2
PbC2	Parke silt loam, 8 to 15 percent slopes, eroded	914	0.3
PbD	Parke silt loam, 15 to 25 percent slopes	381	0.1
PbE	Parke silt loam, 25 to 35 percent slopes	381	0.1
PcB	Parke-Urban land complex, 3 to 8 percent slopes	519	0.2
PcC	Parke-Urban land complex, 8 to 15 percent slopes	320	0.1
RwB2	Russell silt loam, 3 to 8 percent slopes, eroded	1,621	0.6
RxB	Russell-Urban land complex, 3 to 8 percent slopes	8,304	3.1
UgB	Urban land-Elkinsville complex, 3 to 8 percent slopes	1,117	0.4
UgC	Urban land-Elkinsville complex, 8 to 15 percent slopes	722	0.3
Uh	Urban land-Huntington complex, frequently flooded	4,627	1.8
UmB	Urban land-Martinsville complex, 3 to 8 percent slopes	5,253	2.0
UmC	Urban land-Martinsville complex, 8 to 15 percent slopes	431	0.2
	Total	40,164	15.2

Hardin County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam	14	*
MaB	Martinsville loam, 1 to 4 percent slopes	397	0.1
No	Nolin silt loam, occasionally flooded	810	0.3
	Total	1,221	0.4

* Less than 0.1 percent.

Henry County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gm	Genesee loam	372	0.1
Rs	Ross loam	547	0.2

	Total	919	0.3

Highland County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
EkB	Elkinsville silt loam, 1 to 6 percent slopes	14	*
Gd	Gessie loam, frequently flooded	77	*
Ge	Gessie silt loam, occasionally flooded	8	*
Gn	Genesee silt loam	5,829	1.6
HkC2	Hickory silt loam, 6 to 12 percent slopes, moderately eroded	1,741	0.5
HkD2	Hickory silt loam, 12 to 18 percent slopes, moderately eroded	4,538	1.3
HkE2	Hickory silt loam, 18 to 25 percent slopes, moderately eroded	2,235	0.6
HkF2	Hickory silt loam, 25 to 35 percent slopes, moderately eroded	758	0.2
HyC3	Hickory clay loam, 6 to 12 percent slopes, severely eroded	352	*
HyD3	Hickory clay loam, 12 to 18 percent slopes, severely eroded	2,016	0.6
HyE3	Hickory clay loam, 18 to 25 percent slopes, severely eroded	201	*
OcA	Ockley silt loam, 0 to 2 percent slopes	141	*
OcB	Ockley silt loam, 2 to 6 percent slopes	566	0.2
OcC2	Ockley silt loam, 6 to 12 percent slopes, moderately eroded	444	0.1
OdB	Ockley-Urban land complex, gently sloping	40	*
Rn	Ross silt loam	2,944	0.8
RuB	Russell silt loam, 2 to 6 percent slopes	210	*
WvA	Williamsburg silt loam, 0 to 2 percent slopes	91	*
WvB	Williamsburg silt loam, 2 to 6 percent slopes	350	*
WvC	Williamsburg silt loam, 6 to 12 percent slopes	256	*
	Total	22,811	6.4

* Less than 0.1 percent.

Hocking County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AfB	Alford silt loam, 2 to 6 percent slopes	269	*
AfC	Alford silt loam, 6 to 12 percent slopes	638	0.2
AgB	Allegheny loam, 2 to 6 percent slopes	235	*
AgC	Allegheny loam, 6 to 12 percent slopes	242	*
Cg	Chagrin silt loam, frequently flooded	13,498	5.0
HcD2	Hickory-Gilpin complex, 12 to 20 percent slopes, eroded	62	*
HkD2	Hickory silt loam, 12 to 20 percent slopes, eroded	2	*
HkE2	Hickory silt loam, 20 to 35 percent slopes, eroded	46	*
HmC2	Hickory silt loam, 6 to 12 percent slopes, eroded	1	*
HmD2	Hickory silt loam, 12 to 18 percent slopes, eroded	1,380	0.5
HmE	Hickory silt loam, 20 to 35 percent slopes, eroded	746	0.3
HmF	Hickory silt loam, 25 to 40 percent slopes	464	0.2
HrE	Hickory-Germano complex, 20 to 35 percent slopes	13	*
PkC2	Pike silt loam, 6 to 12 percent slopes, eroded	2	*
Po	Pope loam, occasionally flooded	2,169	0.8

RcD	Richland loam, 15 to 25 percent slopes	5	*
	Total	19,772	7.3

* Less than 0.1 percent.

Jackson County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AkB	Allegheny loam, 3 to 8 percent slopes	319	0.1
AkC	Allegheny loam, 8 to 15 percent slopes	766	0.3
AkD	Allegheny loam, 15 to 25 percent slopes	2,166	0.8
Cu	Cuba silt loam, occasionally flooded	752	0.3
Ha	Haymond silt loam, occasionally flooded	10	*
	Total	4,013	1.5

* Less than 0.1 percent.

Jefferson County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
RaB	Richland silt loam, 2 to 6 percent slopes	68	*
RcB	Richland silt loam, 1 to 7 percent slopes	3,975	1.5
RcC	Richland silt loam, 7 to 15 percent slopes	200	*
	Total	4,243	1.6

* Less than 0.1 percent.

Lawrence County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Cg	Chagrin loam, frequently flooded	3,863	1.3
Ch	Chagrin silt loam, frequently flooded	63	*
Cu	Cuba silt loam, occasionally flooded	3,570	1.2
EkB	Elkinsville silt loam, 1 to 6 percent slopes	3,050	1.0
EkE	Elkinsville silt loam, 15 to 40 percent slopes	366	0.1
EmB	Elkinsville-Urban land complex, 1 to 8 percent slopes	3,657	1.3
	Total	14,569	5.0

* Less than 0.1 percent.

Licking County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AcB	Alford silt loam, 2 to 8 percent slopes	35	*
AcC2	Alford silt loam, 8 to 15 percent slopes, eroded	5	*
AfA	Alford silt loam, 0 to 2 percent slopes	610	0.1
AfB	Alford silt loam, 2 to 6 percent slopes	3,105	0.7
AfC2	Alford silt loam, 6 to 12 percent slopes, eroded	705	0.2
AhB	Alford-Urban land complex, 2 to 6 percent slopes	500	0.1
HkC2	Hickory silt loam, 6 to 12 percent slopes, eroded	490	0.1
HkD2	Hickory silt loam, 12 to 18 percent slopes, eroded	265	*
MnA	Mentor silt loam, 0 to 2 percent slopes	520	0.1
MnB	Mentor silt loam, 2 to 6 percent slopes	3,405	0.8
MnC2	Mentor silt loam, 6 to 12 percent slopes, eroded	4,080	0.9

MnD2	Mentor silt loam, 12 to 18 percent slopes, eroded	370	*
PaC2	Parke silt loam, 6 to 12 percent slopes, eroded	2,250	0.5
RsA	Rush silt loam, 0 to 2 percent slopes	975	0.2
	Total	17,315	3.9

* Less than 0.1 percent.

Logan County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam	1,371	0.5
	Total	1,371	0.5

Lorain County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
MnB	Mentor silt loam, 2 to 6 percent slopes	434	0.1
MnC	Mentor silt loam, 6 to 12 percent slopes	127	*
MnE	Mentor silt loam, 12 to 25 percent slopes	104	*
	Total	665	0.2

* Less than 0.1 percent.

Lucas County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
SmB	Sisson loam, 2 to 6 percent slopes	451	0.2
SmC	Sisson loam, 6 to 12 percent slopes	614	0.3
SmD	Sisson loam, 12 to 18 percent slopes	826	0.4
SnB	Sisson-Urban land complex, 2 to 12 percent slopes	1,546	0.7
	Total	3,437	1.5

Madison County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Rs	Ross silt loam, occasionally flooded	987	0.3
	Total	987	0.3

Mahoning County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
WrF2	Wooster loam, 25 to 50 percent slopes, moderately eroded	247	*
WsB	Wooster silt loam, 2 to 6 percent slopes	2,068	0.8
WsC2	Wooster silt loam, 6 to 12 percent slopes, moderately eroded	3,837	1.4
WsD2	Wooster silt loam, 12 to 18 percent slopes, moderately eroded	571	0.2
WsE2	Wooster silt loam, 18 to 25 percent slopes, moderately eroded	88	*
	Total	6,811	2.5

* Less than 0.1 percent.

Marion County, Ohio

Map Symbol	Soil Name	Acres	Percent of County

MaA	Martinsville loam, 0 to 2 percent slopes	880	0.3
MaB	Martinsville loam, 2 to 6 percent slopes	477	0.2
No	Nolin silt loam, occasionally flooded	3,773	1.5
Ro	Rossburg silt loam, 0 to 2 percent slopes, occasionally flooded	4	*
	Total	5,134	2.0

* Less than 0.1 percent.

Medina County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Cr	Chagrin silt loam, occasionally flooded	59	*
MoB	Mentor silt loam, 2 to 6 percent slopes	4	*
WvB	Wooster-Riddles silt loams, 2 to 6 percent slopes	49	*
WvC2	Wooster-Riddles silt loams, 6 to 12 percent slopes, eroded	188	*
WvD2	Wooster-Riddles silt loams, 12 to 18 percent slopes, eroded	11	*
	Total	311	0.1

* Less than 0.1 percent.

Meigs County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Cg	Chagrin silt loam, frequently flooded	10,689	3.9
DuC	Duncannon silt loam, 6 to 12 percent slopes	227	*
EkA	Elkinsville silt loam, 0 to 2 percent slopes	261	*
GaC	Gallia loam, 6 to 12 percent slopes	802	0.3
GaD	Gallia loam, 12 to 18 percent slopes	255	*
Mo	Moshannon silt loam, frequently flooded	1,264	0.5
RcB	Richland silt loam, 2 to 6 percent slopes	1,071	0.4
RdD	Richland loam, 15 to 25 percent slopes	3	*
RdE	Richland loam, 25 to 40 percent slopes	1	*
	Total	14,573	5.3

* Less than 0.1 percent.

Mercer County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam	1,816	0.6
	Total	1,816	0.6

Miami County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Rs	Ross silt loam	2,876	1.1
	Total	2,876	1.1

Monroe County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AlD	Allegheny silt loam, 12 to 18 percent slopes	1	*
AsA	Ashton silt loam, 0 to 3 percent slopes	192	*
Cg	Chagrin silt loam	5,942	2.0
Hu	Huntington silt loam	737	0.3
	Total	6,872	2.3

* Less than 0.1 percent.

Montgomery County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Rs	Ross silt loam	10,731	3.6
Rt	Ross-Urban land complex	3,786	1.3
	Total	14,517	4.9

Morgan County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Ca	Chagrin silt loam, frequently flooded	327	0.1
RvE	Richland-Vandalia complex, 20 to 35 percent slopes	53	*
	Total	380	0.1

* Less than 0.1 percent.

Morrow County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
ObA	Ockley loam, 0 to 2 percent slopes	3	*
ObB	Ockley loam, 2 to 6 percent slopes	69	*
	Total	72	0.0

* Less than 0.1 percent.

Muskingum County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AfB	Alford silt loam, 2 to 8 percent slopes	5,395	1.3
AfC2	Alford silt loam, 8 to 15 percent slopes, eroded	5,545	1.3
Cb	Chagrin loam, rarely flooded	2,277	0.5
LcD	Lakin-Alford complex, 15 to 25 percent slopes	541	0.1
No	Nolin silt loam, occasionally flooded	4,638	1.1
UtA	Urban land-Nolin complex, rarely flooded	593	0.1
	Total	18,989	4.4

Noble County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AlD	Allegheny silt loam, 12 to 18 percent slopes	9	*
Ch	Chagrin silt loam, occasionally flooded	1,990	0.8
RcD	Richland channery loam, 15 to 25 percent slopes	16	*

	Total	2,015	0.8

* Less than 0.1 percent.

Ottawa County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam, frequently flooded	1,041	0.6
	Total	1,041	0.6

Perry County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AfB	Alford silt loam, 1 to 8 percent slopes	6,773	2.6
AfC	Alford silt loam, 8 to 15 percent slopes	1,862	0.7
AfC2	Alford silt loam, 8 to 15 percent slopes, eroded	107	*
AfD	Alford silt loam, 15 to 25 percent slopes	282	0.1
AgB	Alford silt loam, 2 to 8 percent slopes	3	*
MeB	Mentor silt loam, gravelly substratum, 1 to 8 percent slopes	836	0.3
MeC	Mentor silt loam, gravelly substratum, 8 to 15 percent slopes	1,137	0.4
No	Nolin silt loam, occasionally flooded	3,510	1.3
SfD	Shelocta-Cruze complex, 15 to 25 percent slopes	1	*
SfE	Shelocta-Cruze complex, 25 to 40 percent slopes	26	*
	Total	14,537	5.5

* Less than 0.1 percent.

Pickaway County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam, occasionally flooded	9,332	2.9
Gs	Gessie silt loam, occasionally flooded	47	*
Rt	Ross silt loam, overwash, frequently flooded	801	0.2
WeA	Wea silt loam, 0 to 2 percent slopes	1,965	0.6
WeB	Wea silt loam, 2 to 6 percent slopes	476	0.1
	Total	12,621	3.9

* Less than 0.1 percent.

Pike County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
En	Elkinsville silt loam, rarely flooded	2,182	0.8
Ge	Genesee silt loam, occasionally flooded	6,699	2.4
Gf	Gessie silt loam, occasionally flooded	72	*
Ha	Haymond silt loam, occasionally flooded	2,705	1.0
Hu	Huntington silt loam, occasionally flooded	3,637	1.3
Mh	Martinsville loam, rarely flooded	727	0.3
Mt	Mentor silt loam, rarely flooded	117	*
PaA	Parke silt loam, 0 to 3 percent slopes	639	0.2
PaB	Parke silt loam, 3 to 8 percent slopes	212	*

SuB	Spargus channery silt loam, 2 to 6 percent slopes	7	*
	Total	16,997	6.0

* Less than 0.1 percent.

Portage County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Tg	Tioga loam	1,055	0.3
	Total	1,055	0.3

Preble County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
RuB	Russell silt loam, 2 to 6 percent slopes	2,857	1.0
	Total	2,857	1.0

Putnam County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam	1,807	0.6
Kw	Knoxdale silt loam, occasionally flooded	10	*
Rw	Rossburg silt loam, occasionally flooded	33	*
	Total	1,850	0.6

* Less than 0.1 percent.

Richland County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
MeB	Mentor silt loam, 2 to 6 percent slopes	267	*
MeC	Mentor silt loam, 6 to 12 percent slopes	198	*
WeD	Westmoreland silt loam, 12 to 18 percent slopes	102	*
WmD	Wheeling and Mentor silt loams, 12 to 18 percent slopes	301	*
	Total	868	0.3

* Less than 0.1 percent

Ross County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Ge	Gessie silt loam, occasionally flooded	17,914	4.0
Gf	Gessie silt loam, frequently flooded	5,601	1.3
Hd	Haymond silt loam, occasionally flooded	2,911	0.7
HkD2	Hickory silt loam, 12 to 20 percent slopes, eroded	131	*
HkE2	Hickory silt loam, 20 to 35 percent slopes, eroded	329	*
Ht	Huntington silt loam, occasionally flooded	245	*
McA	Martinsville loam, rarely flooded	166	*
MeC2	Mentor silt loam, 6 to 12 percent slopes, eroded	702	0.2
MeD2	Mentor silt loam, 12 to 20 percent slopes, eroded	512	0.1
MfA	Mentor silt loam, rarely flooded	561	0.1
MgA	Mentor silt loam, gravelly substratum, 0 to 2 percent slopes	2,914	0.7
MgB	Mentor silt loam, gravelly substratum, 2 to 6 percent slopes	657	0.1

PkA	Pike silt loam, 0 to 2 percent slopes	1,873	0.4
PkB	Pike silt loam, 2 to 6 percent slopes	1,355	0.3
SuB	Spargus channery silt loam, 2 to 6 percent slopes	1,259	0.3
	Total	37,130	8.4

* Less than 0.1 percent.

Sandusky County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
MeB	Mentor silt loam, 1 to 4 percent slopes	1,277	0.5
MeF	Mentor silt loam, 25 to 50 percent slopes	756	0.3
	Total	2,033	0.8

Scioto County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AfD	Alford silt loam, 10 to 25 percent slopes	660	0.2
Cu	Cuba silt loam, occasionally flooded	1,280	0.3
EhB	Elkinsville silt loam, 1 to 6 percent slopes	12	*
EkB	Elkinsville silt loam, 1 to 8 percent slopes	2,768	0.7
EkE	Elkinsville silt loam, 25 to 40 percent slopes	1,679	0.4
EmB	Elkinsville-Urban land complex, 1 to 8 percent slopes	1,541	0.4
Ge	Genesee silt loam, occasionally flooded	2,365	0.6
Ha	Haymond silt loam, occasionally flooded	3,054	0.8
Hu	Huntington silt loam, occasionally flooded	522	0.1
No	Nolin silt loam, occasionally flooded	12,086	3.1
SbB	Shelocta silt loam, 3 to 8 percent slopes	10,880	2.8
SbC	Shelocta silt loam, 8 to 15 percent slopes	2,119	0.5
SbD	Shelocta silt loam, 15 to 25 percent slopes	3,584	0.9
WmB	Wheeling silt loam, 1 to 8 percent slopes	1,450	0.4
	Total	44,000	11.2

* Less than 0.1 percent.

Seneca County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Ch	Chagrin silt loam, occasionally flooded	5,427	1.5
Ge	Genesee silt loam, occasionally flooded	157	*
Ru	Ross silt loam, occasionally flooded	1,170	0.3
	Total	6,754	1.9

* Less than 0.1 percent.

Shelby County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Ge	Genesee silt loam, occasionally flooded	1,108	0.4
	Total	1,108	0.4

Stark County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
MeA	Mentor silt loam, 0 to 2 percent slopes	270	*
MeB	Mentor silt loam, 2 to 6 percent slopes	447	0.1
MeC	Mentor silt loam, 6 to 12 percent slopes	237	*
MeD	Mentor silt loam, 12 to 18 percent slopes	176	*
RuA	Rush silt loam, 0 to 3 percent slopes	---	*
WuB	Wooster silt loam, 2 to 6 percent slopes	6,487	1.7
WuC	Wooster silt loam, 6 to 12 percent slopes	3,816	1.0
WuC2	Wooster silt loam, 6 to 12 percent slopes, moderately eroded	10,791	2.9
WuD2	Wooster silt loam, 12 to 18 percent slopes, moderately eroded	6,137	1.7
WuE2	Wooster silt loam, 18 to 25 percent slopes, moderately eroded	1,538	0.4
WuF2	Wooster silt loam, 25 to 50 percent slopes, moderately eroded	143	*
WvD	Wooster-Urban land complex, steep	305	*
WxB	Wooster-Riddles silt loams, 2 to 6 percent slopes	---	*
WxC	Wooster-Riddles silt loams, 6 to 12 percent slopes	---	*
WxC2	Wooster-Riddles silt loams, 6 to 12 percent slopes, eroded	---	*
WxD2	Wooster-Riddles silt loams, 12 to 18 percent slopes, eroded	---	*
	Total	30,347	8.2

* Less than 0.1 percent.

Summit County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
CwC2	Chili-Wooster complex 6 to 12 percent slopes, moderately eroded	449	0.2
CwD2	Chili-Wooster complex, 12 to 18 percent slopes, moderately eroded	275	0.1
CwE2	Chili-Wooster complex, 18 to 25 percent slopes, moderately eroded	232	*
WwD	Wooster-Urban land complex, hilly	300	0.1
WyC2	Wooster-Riddles silt loams, 6 to 12 percent slopes, eroded	4	*
	Total	1,260	0.5

* Less than 0.1 percent.

Tuscarawas County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
EkA	Elkinsville silt loam, 0 to 3 percent slopes	600	0.2
MeB	Mentor silt loam, 2 to 6 percent slopes	2	*
RuA	Rush silt loam, 0 to 3 percent slopes	3,322	0.9
	Total	3,924	1.1

* Less than 0.1 percent.

Union County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam	3,006	1.1
No	Nolin silt loam, 0 to 2 percent slopes, occasionally flooded	35	*
RpA	Rossburg silt loam, 0 to 2 percent slopes, occasionally flooded	2	*
	Total	3,043	1.1

* Less than 0.1 percent.

Vinton County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Cg	Chagrin silt loam, 0 to 2 percent slopes, frequently flooded	4,434	1.7
RcD	Richland loam, 15 to 25 percent slopes	29	*
RcE	Richland loam, 25 to 40 percent slopes	48	*
	Total	4,511	1.7

* Less than 0.1 percent.

Warren County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
CqC2	Crouse-Miamian silt loams, 6 to 12 percent slopes, eroded	94	*
CrB	Crider silt loam, 2 to 6 percent slopes	333	0.1
Gd	Genesee fine sandy loam	4,515	1.7
Gn	Genesee loam	4,612	1.8
HiD2	Hickory silt loam, 12 to 18 percent slopes, eroded	220	*
HiE2	Hickory silt loam, 18 to 25 percent slopes, eroded	7	*
HiF2	Hickory silt loam, 25 to 35 percent slopes, eroded	279	0.1
HmE	Hennepin-Miamian silt loams, 18 to 25 percent slopes	240	*
HmE2	Hennepin-Miamian silt loams, 18 to 25 percent slopes, moderately eroded	1,654	0.6
HnD3	Hennepin-Miamian complex, 12 to 18 percent slopes, severely eroded	399	0.2
HuE2	Hickory-Morrisville silt loams, 18 to 25 percent slopes, eroded	27	*
PaB	Parke silt loam, 2 to 6 percent slopes	224	*
PaD2	Parke silt loam, 6 to 18 percent slopes, moderately eroded	183	*
Rn	Ross loam	3,598	1.4
WlA	Williamsburg silt loam, 0 to 2 percent slopes	156	*
WlB	Williamsburg silt loam, 2 to 6 percent slopes	529	0.2
WlC2	Williamsburg silt loam, 6 to 12 percent slopes, moderately eroded	166	*
	Total	17,236	6.6

* Less than 0.1 percent.

Washington County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AlB	Allegheny silt loam, 2 to 6 percent slopes	536	0.1
AlC	Allegheny silt loam, 6 to 12 percent slopes	1,801	0.4
AlD	Allegheny silt loam, 12 to 18 percent slopes	1,479	0.4
AlG	Allegheny silt loam, 18 to 50 percent slopes	497	0.1
AsA	Ashton silt loam, 0 to 2 percent slopes	631	0.2
AsB	Ashton silt loam, 2 to 6 percent slopes	101	*
Cg	Chagrin silt loam	7,284	1.8
DtB	Duncannon silt loam, 2 to 6 percent slopes	156	*
DtC	Duncannon silt loam, 6 to 12 percent slopes	147	*
DuD	Duncannon-Lakin complex, 12 to 18 percent slopes	205	*
DuE	Duncannon-Lakin complex, 18 to 25 percent slopes	373	*
GaB	Gallia silt loam, 2 to 6 percent slopes	441	0.1
GaC	Gallia silt loam, 6 to 12 percent slopes	1,433	0.4
GaD	Gallia silt loam, 12 to 18 percent slopes	341	*

HcA	Hackers silt loam, 0 to 2 percent slopes	948	0.2
HcB	Hackers silt loam, 2 to 6 percent slopes	1,758	0.4
HcC	Hackers silt loam, 6 to 12 percent slopes	198	*
Hu	Huntington silt loam	852	0.2
MeA	Mentor silt loam, 0 to 2 percent slopes	2,182	0.5
MeB	Mentor silt loam, 2 to 6 percent slopes	1,991	0.5
MeC	Mentor silt loam, 6 to 12 percent slopes	611	0.1
Mp	Moshannon silt loam	6,621	1.6
No	Nolin silt loam	2,891	0.7
	Total	33,477	8.2

* Less than 0.1 percent.

Wayne County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
RhB	Riddles silt loam, 2 to 6 percent slopes	2,444	0.7
RhC	Riddles silt loam, 6 to 12 percent slopes	2,359	0.7
RhD2	Riddles silt loam, 12 to 18 percent, eroded	1,069	0.3
RhE	Riddles silt loam, 18 to 25 percent slopes	2,500	0.7
WuB	Wooster-Riddles silt loams, 2 to 6 percent slopes	23,623	6.6
WuC	Wooster-Riddles silt loams, 6 to 12 percent slopes	6,927	1.9
WuC2	Wooster-Riddles silt loams, 6 to 12 percent slopes, eroded	15,191	4.3
WuD2	Wooster-Riddles silt loams, 12 to 18 percent slopes, eroded	6,816	1.9
	Total	60,929	17.1

Williams County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Ge	Genesee loam	1,396	0.5
	Total	1,396	0.5

Wood County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gm	Genesee loam	385	*
Gn	Genesee silt loam	777	0.2
	Total	1,162	0.3

* Less than 0.1 percent.

Wyandot County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AdC2	Alexandria silt loam, 6 to 12 percent slopes, moderately eroded	1	*
Cm	Chagrin silt loam, rarely flooded	871	0.3
Ge	Genesee silt loam, occasionally flooded	4,143	1.6
HpE	Hennepin-Alexandria silt loams, 18 to 50 percent slopes	1	*
MaB	Martinsville fine sandy loam, 2 to 6 percent slopes	591	0.2
SfC2	Shinrock-Martinsville complex, 6 to 12 percent slopes, eroded	1,638	0.6
SfD2	Shinrock-Martinsville complex, 12 to 18 percent slopes, eroded	246	*
	Total	7,501	2.9

* Less than 0.1 percent.

Appendix 7: Planning for Streams

Introduction

Many stream alterations made during development will be responsible for their future quality. In this respect, the window of time before development is complete is an opportunity to protect existing stream integrity, correct degraded conditions or alternatively cause or allow worsening of the overall stream and water quality. This document lays out critical objectives that must be met in order to protect the long-term stream integrity.

As Figure 1 illustrates below, there are many variables responsible for stream integrity. Most frequently monitored stream characteristics, such as the water chemistry, habitats features or the biota found in the stream, are the result of other variables. Some variables, such as geology or rainfall (on the far left of the diagram) aren't significantly affected during development. Stream flow and stream form (morphology) are often significantly changed during development and often negatively influence stream integrity. This document focuses primarily on the need to build desired characteristics on practical steps of physical stream integrity. Site hydrology and stream flow are not discussed here, since they are subject of stormwater detention and development standards. Stream form or morphology is the primary concern here, since changes to stream form subsequently impact stream functions and characteristics such as water quality or habitat.

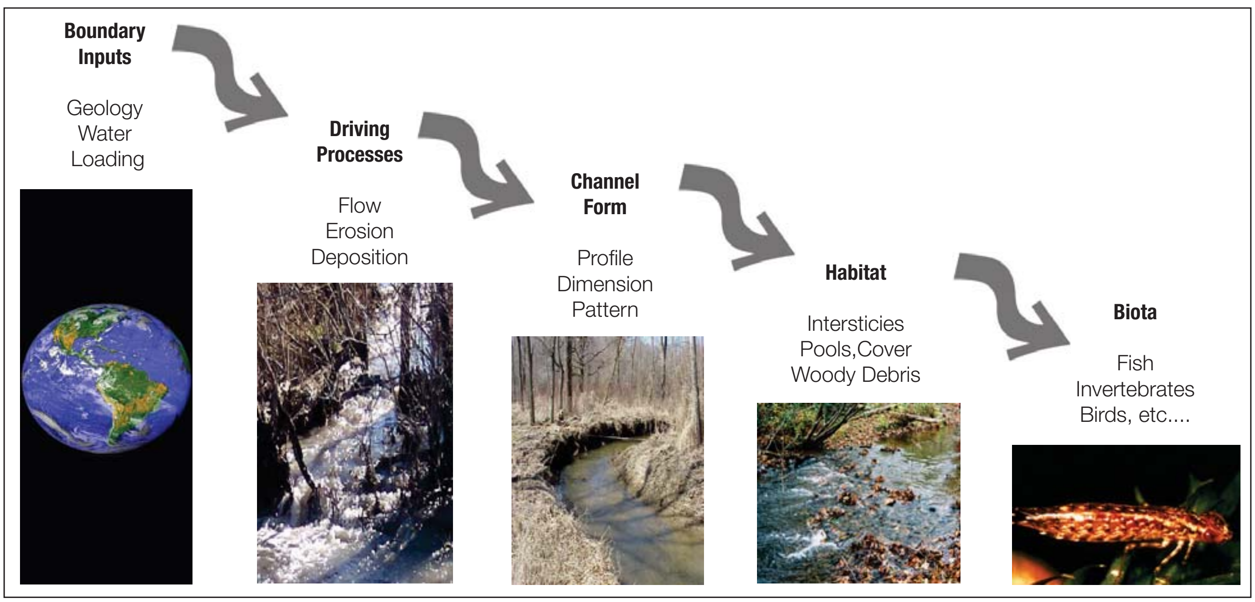
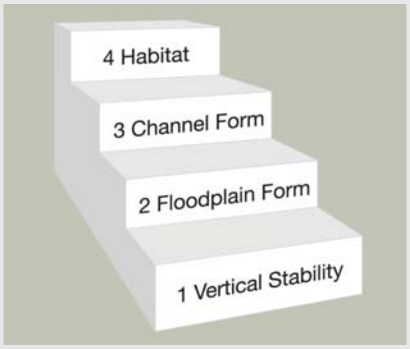


Figure 1 Relationship of the stream variables responsible for stream integrity

Initial stream conditions vary from site to site, therefore addressing physical integrity of a stream should start with an assessment of the channel morphology. Site designers should first have a sense of the morphology issues not just at one stream reach, but also of the entire drainage network. While quantitative measures are useful, gathering data must not distract designer from understanding what is good and bad about the physical conditions of a drainage network. Of course, existing condition is not always the best point of reference, therefore many tools, such as reference conditions or stream classification systems will be very useful for comparing current condition to stable natural forms.

Use prioritized objectives (Figure 2) when planning, designing or altering channels in Ohio. Ultimately prioritizing issues is essential for success and this guidance describes aspects of morphology that are most fundamental to overall stream health. These objectives are hierarchical; therefore you must begin with the most critical aspect of stream form and build upon these.

Planning for Quality Streams Requires Prioritizing Objectives



Prioritized Objective	Prerequisite
1. Vertical Stability	
2. Floodplain Form	Vertical Stability
3. Channel Form	Floodplain Form and Function
4. Habitat	Dependent on Objectives 1, 2, and 3

Figure 2 Planning for quality streams requires prioritizing objectives

Objective 1: Vertical Channel Stability

Vertically stable streams are in a dynamic equilibrium, maintaining a balance between bed material transport and supply. Vertical *instability* can be exhibited as either degrading (also known as incising or downcutting) or aggrading (depositing or filling up), although degradation is by far the most common vertical instability threat to Ohio streams.

Physical degradation is caused by increased bed load transport, perhaps the result of increasing runoff (e.g. urbanization), shortening stream length, and restricting floodplains. Reduced bed load supply also causes downcutting in channels such as from "hardening" headwater channels or when dams trap bed load. When more bed material is washed away than is supplied, incision or downcutting results as is shown in Figure 2, leading to channels becoming deeper and more entrenched. "Entrenched" describes channels that have reduced access to their floodplains and less interaction with riparian areas.

In Ohio, low gradient entrenched channels are characterized by low stream quality and often long-term instability exhibited in excess bed and bank erosion. Even high quality streams that are not vertically stable are in the process of degradation and will continue to have positive characteristics diminished or lost over time. Vertical stability is necessary for every other desired characteristic of channel morphology.

Headcut shown in an incising stream

Assessment

A variety of approaches exist for evaluating vertical stability, including very sophisticated sediment transport models, threshold of motion criteria for bed materials, ratio of bank height to bankfull channel depth, or simple observation (Table 1). More rigorous evaluations may be appropriate where existing conditions are already vertically unstable and the consequence of failure is severe. Where proposed changes to a stream have no potential to decrease vertical stability, more simplified evaluation approaches become appropriate.

Table 1 General indicators of vertical instability or stability

Instability		Stability
Headcuts		
Near vertical banks accompanied by bank erosion		
Bank Height Ratio		Bank Height Ratio
Moderately Unstable	1.06 -1.3	near 1.1
Unstable:	1.3 - 1.5	
Highly Unstable:	exceeds 1.5	

Note: Bank height ratio is the height of the bank (from the thalweg) divided by the height of the bankfull channel. See Rosgen, D.L. 2001. A Stream Channel Stability Assessment Methodology. A Practical Method of Computing Streambank Erosion Rate. In: 7th Federal Interagency Sedimentation Conference, March 25-29, Reno, Nev.

For example, vertical stability is typically not a concern for low energy streams, particularly where straight, entrenched, low-gradient channels, such as drainage ditches are expected to gain floodplain and stream length through proposed changes. Conversely, reducing stream length, which increases stream slope may induce downcutting in many Ohio channels.

Actions

Solutions to vertical instability may include system-wide solutions such as watershed-scale stormwater management that better controls higher energy runoff events and prevents or manages the initial causes of downcutting. Solutions may also focus on site level tools such as the construction of grade control riffles, cross vanes, w-weirs or even designing culverts to prevent further downcutting[1]. General approaches to addressing incised streams are described by Rosgen 1997[2].

1 Newbury, R.W. and Gaboury, M.N. Stream analysis and Fish Habitat Design: A Field Manual. Newbury Hydraulics Ltd. Manitoba Habitat Heritage Corporation and Manitoba Fisheries Branch. 1993.

Maryland Department of the Environment (MDE) Water Management Administration. 2000. Maryland's Waterway Construction Guidelines. Available at http://www.mde.state.md.us/assets/document/wetlandswaterways/mgwc.pdf

Department of Conservation and Recreation (DCR), Division of Soil and Water Conservation. 2004 The Virginia Stream Restoration & Stabilization Best Management Practices. Guide Richmond, Virginia. Available at http://www.dcr.virginia.gov/sw/docs/streamguide.pdf

Schueler T., & K. Brown. 2004. Urban Subwatershed Restoration Manual No. 4: Urban Stream Repair Practices. Version 1.0. Center for Watershed Protection.

2 Rosgen, D.L., 1997. A Geomorphological Approach to Restoration of Incised Rivers. Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision.

Objective 2: Floodplain Form

Floodplain form, that is, having access to a functional floodplain at normal flood flows[3] (see Figures 3 and 4) is the most significant aspect of morphology for the long-term integrity of streams and for water quality. Floodplains are nature's primary ways of managing stormwater, improving water quality and organizing substrates for aquatic habitat. Stream processes associated with floodplain form occur in the smallest headwater streams as well as the largest rivers in Ohio, each overflowing their banks during significant storm events. Because maintaining streambed elevation (preventing downcutting and entrenchment) maintains the stream's access to its floodplain at normal flood flows, vertical stability is listed as the first objective in this section. However, maintaining functional floodplain form is the overarching goal and the second objective.

If a stream has access to its floodplain, during high flows:

- the erosive energy of the stream is dissipated by spreading the flow across the floodplain;
- the lower velocities associated with shallow flow on the floodplain allow eroded sediment and other pollutants to be settled out of the flow;
- flood waters infiltrate into the shallow groundwater that sustains stream baseflow.

When streams become entrenched (i.e., when they downcut and lose access to their floodplain) beneficial channel processes are lost or diminished. With entrenched streams, all of the erosive energy, eroded sediments and polluted runoff are contained within the channel and passed downstream where they cause channel incision, excessive streambank erosion, localized flooding and degraded stream habitat.

The vast majority of natural streams have extensive floodplains that are saturated or inundated several times a year. This is characteristic of streams with slopes less then 2%. The average stream slope in Ohio
is only 0.3%. The stability of steeper streams is also dependent on appropriate floodplain widths, but these are generally narrower with increasing slope.

Streams beginning to utilize floodplains

Channels with limited floodplain form

3 The term "normal flood flows" equates to the typical out-of-bank events that occur under natural watershed and stream conditions. In undeveloped areas, most streams will flood (i.e., get out of bank) two or three times per year. In urban and suburban areas, streams typically may experience 5 to as many as 20 out of bank events per year.

When floodplains are extensive, low and frequently wet, streams have a tremendous ability to assimilate pollutants. Additionally, these streams are more resilient, and more resistant to watershed impacts.

Furthermore, while recovery of stream integrity is possible, the "natural" redevelopment of floodplain is the aspect that takes the most time, being measured in terms of years and perhaps decades. While floodplain recovery is ultimately positive, it is also associated with highbanks being lowered through bank erosion and subquently higher sediment loads until an adequate floodplain width is achieved. Thus it is much less likely to be allowed to occur where intensive land uses have encroached near the channel and will likely not occur in low energy (lower gradient) channels such as ditches.

Assessment

The quality of floodplain form is first an issue of elevation or how accessible it is (Figure 3) and second an issue of how extensive or wide it is (Figure 4). Ideally floodplain elevations are at and below "bankfull stage" and allow the ground surface to be saturated or inundated several times per year for most channels. Floodplain elevation can be quantified a number of ways including the ratio of the height of the floodplain relative to the bankfull channel depth, frequency of inundation, or relative depth of a particular flow event (usually in terms of recurrence interval).

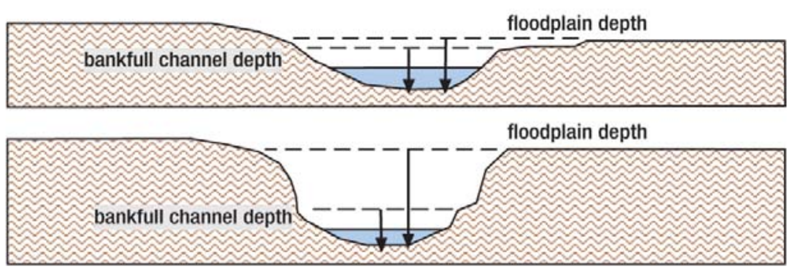


Figure 3 Appropriate floodplain form is first an issue of elevation

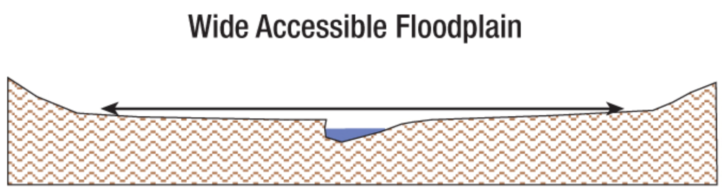


Figure 4 Appropriate floodplain form is also an issue of extent or width

Given the variability in natural channels, defining adequate floodplain width is understandably imprecise. One potential target is pre-disturbance conditions. Another is the width of the meander pattern past, present or projected. For most streams it is simply a matter of the more floodplain width, the better. However, floodplain immediately adjacent to the channel is most critical and diminishes in importance with increasing distance from the channel. Since floodplain width comes at a cost and may conflict with other land uses, a definition of ranges of floodplain width is provided below. Adequate floodplain (for streams that naturally have floodplain) is defined by the three descriptive reference points given below.

Floodplain width dimensions defined here are in multiples of the bankfull channel width[4] (Figure 5).

THREE TIMES the bankfull width is the bare minimum. Below this threshold streams are characterized by poor quality, lateral instability, degraded habitat and minimal or no watershed benefit.

FIVE TIMES the bankfull width is frequently associated with fairly good streams. Clear ecological benefits are associated with floodplains of this width. Flood hydraulics and sediment transport exhibit a break at about this floodplain width, with bedload transport (and subsequent channel instability) increasing at a faster rate below this point. Lastly, common meander pattern beltwidths begin to be restricted below this floodplain width.

TEN TIMES the bankfull width and greater is typical of the highest quality streams, undeveloped conditions and streams that provide considerable downstream benefit through their assimilative capacity and hydrologic functions.

A number of indications and arguments suggest 10 times the channel width is a general threshold above which floodplain width does not limit stream quality[5]. Below this threshold the floodplain width appears to begin limiting stream quality, changing the hydraulics and interactions between the channel and floodplain (Ward, 2002[6]). The effects are gradual until the floodplain is reduced to a width somewhere around 5 times the channel width. Floodplain widths below 5 times bankfull width exhibit consistently lower stream quality and reduced floodplain services until the lowest threshold is reached around 3 times the channel width. Below 3 times the bankfull channel width, streams typically cannot maintain a stable floodplain form. The instability problems equate to a loss of services locally and an increasing contribution to stability, water quality and habitat problems downstream.

Using channel width to determine appropriate floodplain width can be problematic due to variability of apparent bankfull channel width and subjectivity involved in stream measurements. Drainage area provides a more robust variable for programs requiring appropriate floodplain widths be applied to channel projects. By using empirical relationships of channel dimension, meanders and watershed size, equations can be generated relating the target floodplain width to drainage area. This approach also can be tailored more to particular watersheds as additional data for an area becomes available. The following equations utilize empirical relationships for channel dimensions, drainage area and meander beltwidth from Dunne & Leopold (1978[7]) and Williams (1986[8]) for the three floodplain-width thresholds described earlier.

$$BW_{10}=147(\text{Drainage Area})^{0.38} \qquad BW_{5}=74(\text{Drainage Area})^{0.38} \qquad BW_{3}=44(\text{Drainage Area})^{0.38}$$

Where BW_x = beltwidth or floodplain width associated with x times the channel width (feet)
Drainage Area = contributing watershed area (square miles)

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4 Floodplain width refers to the width that is saturated or inundated by bankfull flow. It is generally the width of flow just above the bankfull stage. More information regarding means of estimating is available in the Stream Setback practice in Chapter 2.

5 High quality E-4 stream types naturally have very wide floodplains; 57 times the channel width is the average of Rosgen's Classification references. Rosgen, D.L. (1994). A classification of natural rivers. Catena, Vol. 22, 169-199. Elsevier Science, B.V. Amsterdam.

6 Ward, A., D. Mecklenburg, J. Mathews and D. Farver. 2002. Sizing Stream Setbacks to Help Maintain Stream Stability. American Society of Agricultural Engineers Paper Number 022239, for presentation at the 2002 ASAE Annual International Meeting / CIGR XVth World Congress, Chicago, IL. 35 pp.

7 Dunne, T. and L.B. Leopold, 1978. Water in Environmental Planning. W.H. Freeman, New York, 818p.

8 Williams, G.P., 1986. River meanders and channel size. Journal of Hydrology, 88 pp.147-164

Actions

Desirable floodplain form can be protected by restricting floodplain fill and levee construction, in addition to the actions described for controlling down cutting in objective 1. Options for improving floodplain form are: 1) lowering the ground adjacent to the channel to create active floodplain; 2) raising the streambed elevation to connect channel with abandoned floodplain; 3) create a overly wide channel where floodplain deposition and formation can occur; 4) lower banks to increase floodwater access; and 5) utilize stormwater or conservation easements to allow areas where natural erosion and deposition processes are creating improved floodplain form overtime. These options are not all equally beneficial and solutions to better floodplain form may involve some combination of approaches that fit the site and watershed constraints. For example, increasing the bed elevation generally requires much less work and utilizes historical floodplain areas, but is often limited by drainage needs or adjacent land uses.

Objective 3: Channel Form

The form of the bankfull channel is represented by the cross sectional dimension, meander pattern and bed profile. While channel form is typically emphasized in design, its relative importance follows vertical stability and floodplain form. Ideally channel form should target the best potential that would naturally be built and maintained by the stream in the particular watershed. Yet actions may vary upon whether the immediate goal is active restoration, rehabilitating a current degraded condition or facilitating natural recovery.

Assessment

A number of channel form assessment and design approaches have been developed (Skidmore et al, 2001[9]). Using a combination of design approaches is appropriate for restoration of channels, especially high quality, large or unstable streams. For less critical projects and lower quality, yet vertically stable streams, more generic channel design may be adequate. Some projects may even involve only floodplain construction with no work done to the bankfull channel.

Commonly used sources of assessment and design information (design approaches) include:

1. **Regime equations (Empirical Design)** The large databases of channel geometry have a statistical advantage in that they are based on many streams and rivers. Their disadvantage is that they provide typical values within a large acceptable range without defining the character of a specific reach. Some resources may found at (www.dnr.state.oh.us/soilandwater/docs/streammorphology).
2. **The Rosgen Classification of Natural Streams** The Rosgen classification of natural streams (Rosgen, 1996[10]) allows a level of refinement, where typical channel geometry is provided for stable channels in a range of valley conditions. Perhaps even more valuable is the Rosgen classification's geometries that are characteristically unstable.
3. **Regional curves** Regional channel geometry curves provide another type of refinement. Like regime equations, which generally provide only a description of a typical stream without accounting for the variability in channel character, regional curves describe channels typical of a region. Typically only three values are provided: bankfull cross sectional area, width, and mean depth. (Since mean depth is defined as area/width, this is really only two variables.) Regional curves are useful for evaluating size as well as width to depth proportions, which may both having regional variability. A regional curve for the Eastern United States is often used for reference in Ohio (Dunne, 1978[11]). It should be noted that proper identification of bankfull stage is critical to the development of regional curves. Additional regional channel geometry resources may be available by contacting the ODNR-DSWC Stormwater and Streams section.

9 Skidmore, P.B., F.D. Shields, M.W. Doyle, & D.E. Miller. 2001. A Categorization of Approaches to Natural Channel Design. Wetlands Engineering and River Restoration Conference 2001. Available at https://fs.ogm.utah.gov/PUB/MINES/AMR_RELATED/NAAMLP/StrmRest/Skidmore.pdf

10 Rosgen, D.L. (1994). A classification of natural rivers. Catena, Vol. 22, 169-199. Elsevier Science, B.V. Amsterdam.

11 Dunne, T. and L.B. Leopold, 1978. Water in Environmental Planning. W.H. Freeman, New York, 818p.

4. **Measured local reference channel (Analog Design)** A reference channel reach near the reach to be designed has the best potential for illustrating and defining the channel variability and character resulting from local climate and geology. Additionally, there is no end to the detail that may be gleaned from a local reference reach. This also highlights a disadvantage – these particular local reaches of interest are most likely reference sites no one has yet published, let alone surveyed. Perhaps the most valuable (and time consuming) design task is surveying a local reference reach, its longitudinal profile, representative cross sections, bed materials and, to a lesser extent, its meander pattern. Numerous references provide descriptions of methods and uses of reference reach information (Harrelson, 1994; Rosgen, 1998; Hey, 2006[12]). The weaknesses of measured local or on-site channel geometry are that a quality reference channel might not exist and it represents a small sample. Thus this approach must be used in conjunction with the prior three approaches for determining stable channel form.

Actions

Actions promoting best potential channel form require understanding of and to varying degrees designing the appropriate bed form, cross-sectional dimension, and the plan form that fit the stream discharge and valley conditions. Types of constructed channel forms can be generally based on the slope of the proposed stream and the valley conditions as: step-pool channels that are generally over 4% slope; top dressed rip-rap channels (equates to B channel in Rosgen Classification System) that are generally 2-4% percent slope; and compound channels for streams generally less than 2% slope. Compound channels are by far the most common to Ohio and are characterized by a smaller channel within a wider active floodplain, which receive flows during large events. Actual channel designs will contain numerous measures related to channel form such as riffle slope, pool depth and other stream features as well as bed material and appropriate bank protection necessary to maintain the form during establishment of vegetation.

Some actions promote the natural recovery of improved channel form. Channel recovery, sometimes called passive restoration (Brookes, 1996[13]), eventually improves each of the 4 prioritized objectives. However the time required for recovering vertical stability is very long. As discussed earlier, recovery of floodplains has significant potential and channels with the greatest potential for recovery in acceptable time frames and with manageable impacts will be those that have simply been straightened without being lowered. Thus facilitating recovery in these channels may be the most realistic approach to improving channel form. Steps include identifying areas where meander pattern is redeveloping, planning for it through set aside, stream setbacks, easements and perhaps even compensating landowners for it, since this usually means immediately adjacent land uses will be threatened. In some streams it may even be possible to initiate channel recovery with selective tree removal or construction of deflectors.

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12 Harrelson, C.C., C. Rawlins, and J. Potyondy, 1994. Stream Channel Reference Sites: An Illustrated Guide to Field Techniques. USDA Forest Service Rocky Mountain Forest and Range Experiment Station General Technical Report RM-245, 67 p. Available at http://www.ohiodnr.com/soilandwater/docs/streammorphology/RM245E.pdf

Rosgen, D.L. 1998. The Reference Reach - a Blueprint for Natural Channel Design. From proceedings of the ASCE Wetlands and Restoration Conference, March, 1998, Denver, Co. Available at http://www.wildlandhydrology.com/assets/The_Reference_Reach_II.pdf

Hey, R.D. 2006 Fluvial Geomorphological Methodology for Natural Stable Channel Design
AWRA No. 02094, Volume 42, Issue 02, pages 357-374

13 Brookes, A. (1996) Floodplain restoration and rehabilitation. In: Anderson, M., Walling, D. and Bates P. (eds.),

Floodplain processes. John Wiley, Chichester. pp. 553–576.

Objective 4: Habitat

Habitat quality is largely dependent on the ability of natural stream characteristics to develop over time. Thus improvements to habitat should not be attempted unless the proceeding objectives have been met. Because habitat is dependant upon the proceeding objectives, it can serve as a valuable indicator of the overall stream morphology. Drawbacks to using habitat as an indicator are that it does not typically identify the underlying problem or help to choose appropriate remediation, nor does it always identify which elements are critical for protection. Yet for many stream projects, providing immediate good quality habitat is an important objective that follows planning for the appropriate stream form.

Assessment

Ohio's Qualitative Habitat Evaluation Index (QHEI, see Rankin, 1989[14]) and Headwater Habitat Evaluation Index (HHEI[15]) offer valuable tools for assessing habitat quality. It should be noted that just as channel morphology is dependent on the characteristics of a particular watershed, the potential for some aspects of habitat are limited by the watershed characteristics and underlying morphological characteristics. For instance, some watersheds do not supply the bed material that will help to raise that portion of the QHEI score. Another example: Excavating pools on a particular reach of stream that are significantly deeper than the range of pool depths from a quality reference channel should not be expected to be maintained over time. Thus habitat should be assessed in the context of the geomorphic factors and the watershed conditions and utilize the best conditions of the watershed as a point of reference.

Actions

At a minimum, sites must be stabilized sufficiently that the previous objectives are not compromised. Ideally if objectives 1-3 have been met, then quality habitat should develop over time (though substantial time may be required). Although this is true, stream projects differ substantially from natural sites that have established vegetation and other features. Some situations may be appropriate for allowing habitat to develop overtime, such as where existing degraded morphology is being rehabilitated or restored. Ultimately this may be determined by the permitting authority. Ideally, each stream project should plan for quality habitat features, even if they are to be gained through natural development and succession.

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14 Rankin, Edward T. 1989. The Qualitative Habitat Evaluation Index (QHEI): Rationale, methods and application. Ohio Environmental Protection Agency, Division of Water Quality Planning and Assessment, Ecological Assessment Section, Columbus, Ohio. At http://www.epa.state.oh.us/dsw/
bioassess/BioCriteriaProtAqLife.html

15 Anderson, P., R. D. Davic, and S. Tuckerman. 2002. Field Evaluation Manual for Ohio's Primary Headwater Habitat Streams. Ohio EPA, Division of Surface Water, Columbus, Ohio. 66 p. Available at http://www.epa.state.oh.us/dsw/wqs/headwaters/PHWHManual_2002_102402.pdf

Where immediate habitat quality is desired, such as areas of particular ecological importance, habitat structure must be part of construction. Promoting high quality habitat may include actions like utilizing placed boulders, particular substrates, root wads, large woody debris, brush layering and vegetative cover appropriate for the watershed. Constructing appropriate habitat will also involve planning for appropriate aquatic species and native vegetation. Some resources help fit habitat applications to particular stream and flow conditions (Newbury, 1993; Rosgen, 1996[16]). Numerous references[17] discuss habitat structures, but do so with varying degrees of appreciation of the importance of tying the habitat features to stable morphology and projected hydraulic conditions. Streams are dynamic and even the best laid plans require monitoring and perhaps adjustment and maintenance. For this reason, easements may be required.

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16 Newbury, R.W. and Gaboury, M.N. 1993 Stream analysis and Fish Habitat Design: A Field Manual. Newbury Hydraulics Ltd. Manitoba Habitat Heritage Corporation and Manitoba Fisheries Branch.

Rosgen, D.L., 2002. Applied River Morphology. Second Edition. Wildland Hydrology, Pagosa Spring, Colorado.

17 Federal Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US gov't). 1998. Stream Corridor Restoration: Principles, Processes, and Practices. GPO Item No. 0120-A; SuDocs No. A 57.6/2:EN 3/PT.653. ISBN-0-934213-59-3.

Maryland Department of the Environment (MDE) Water Management Administration. 2000. Maryland's Waterway Construction Guidelines. Available at http://www.mde.state.md.us/assets/document/wetlandswaterways/mgwc.pdf

Department of Conservation and Recreation (DCR), Division of Soil and Water Conservation. 2004 The Virginia Stream Restoration & Stabilization Best Management Practices Guide. Richmond, Virginia. Available at http://www.dcr.virginia.gov/sw/docs/streamguide.pdf

Schueler T., & K. Brown. 2004. Urban Subwatershed Restoration Manual No. 4: Urban Stream Repair Practices. Version 1.0. Center for Watershed Protection.

Saldi-Caromile, K., K. Bates, P. Skidmore, J. Barenti, D. Pineo. 2004. Stream Habitat Restoration Guidelines: Final Draft. Co-published by the Washington Departments of Fish and Wildlife and Ecology and the U.S. Fish and Wildlife Service. Olympia, Washington. Available at : http://wdfw.wa.gov/hab/ahg/shrg/index.htm

Appendix 8: Glossary

Adsorption: the adhesion of molecules to the surface of a solid or liquid.

Anti-vortex Device: A device placed at the inlet of a pipe spillway to prevent reduction of flow capacity caused by air entrapped by the swirl of inflowing water.

Anaerobic: Conditions free of available oxygen.

Aquatic Bench: A level or gently sloping bench around the inside perimeter of a permanent pool that is less than 1 foot deep. Normally vegetated with emergent plants, the bench augments pollutant removal, provides habitat, conceals hash as water level drops, and enhances safety.

Attenuation: to reduce the amount, volume or concentration of pollutants or surface water.

Bacterial Decomposition or Microbial Decomposition: Microorganisms or bacteria have the ability to degrade organic compounds as food resources and to absorb nutrients and metals into their tissues to support growth.

Bankfull: The flow or stage of a stream at which water just begins to flow from the stream onto the floodplain and is associated with the discharge most effective at moving sediment. Bankfull stage results in the average form or morphology of the stream. It is determined by observing the deposition on point bars, in-stream gravel bars, vegetation, etc.

Baseflow: Minimum, long-persistence flow in streams produced mainly by seepage; sometimes called subsurface flow.

Belt Width: the area of the stream corridor occupied or expected to be occupied by stream meanders.

Best Management Practice (BMP): Techniques used to lessen the environmental impacts of land use. These techniques may involve structures, vegetation, or altering construction operations.

Biofiltration: a term synonymous with bioretention the use of soil media and plant material to remove pollutants from stormwater runoff.

Channel Migration: The lateral movement of streams through natural physical processes over time.

Cluster Development: Residential development that maximizes open space conservation, without reducing overall building density.

Conservation Development: The development of land using alternative layout and building arrangements in order to better conserve open space and retain natural resources.

Contour Line: A line tracing points on the land surface, which are the same elevation. Contour lines drawn for a number of elevations provide a representation of the land's slopes and topography.

Denuded Area: A portion of land surface on which the vegetation or other soil stabilization features have been removed, destroyed, or covered and which may erode.

Detention: Runoff enters an area of detention faster than it leaves. It occurs in depressions, the natural landscape, or constructed stormwater facilities. While detention can be designed into ponds with or without a permanent pool, dry ponds often are referred to as detention ponds.

Detritus: Dead plant, animal, and other organic material consisting mainly of fallen leaves, which provides the primary energy input of typical stream ecosystems.

Design Storm: A rainfall event of specified size and return frequency (e.g., a storm that occurs only once every 2 years), which is used to calculate the runoff volume and peak flow rate.

Dormancy: The condition of a plant or seed in which life functions are virtually at a standstill.

Downcutting: Channel erosion characterized by erosion of the channel bottom causing the channel to deepen and become entrenched. Also referred to as incising.

Earth-disturbing Activity: Any grading, excavating, filling, or other alteration of the earth's surface where natural or man-made ground cover is destroyed.

Emergent Plant: An aquatic plant that is rooted in the sediment but whose leaves are at or above the water surface. Such wetland plants provide habitat for wildlife and waterfowl in addition to removing urban pollutants.

Ephemeral Stream: A watercourse or stream that flows only in response to precipitation.

Exfiltration: The downward movement of runoff through the bottom of an infiltration trench into the ground.

Extended Detention: A stormwater design feature that provides for the gradual release of a volume of stormwater (typically 0.25 - 0.75 inch per impervious acre) over a 24 to 48-hour interval to increase settling of urban pollutants and protect channels from degradation.

Fertilizer Analysis: The percentage composition of fertilizer, expressed in terms of nitrogen, phosphoric acid, and potash. For example, a fertilizer with a 6-12-6 analysis contains 6%' nitrogen (N), 12% available phosphoric acid (P,O,), and 6% water-soluble potash (K,O).

Flood Peak: The highest stage or flow attained by a flood, also known as peak stage.

Flood Plain: The relatively level land to either side of a channel, which is inundated during high flows. It is often used to reference the 100-year flood plain.

Forebay: A distinct area near an inlet of a pond to enhance deposition of incoming sediments.

Freeboard: Vertical distance between the maximum water surface elevation anticipated and the maximum elevation possible. For dams and diversions it is the difference between the highest water expected and the point the embankment is overtopped, likely resulting in failure of the structure.

Frequency Year Storm: A rainfall event of a magnitude with a specified average recurrence interval. In Ohio, it is calculated usually calculated using the Natural Resources Conservation Service type II 24-hour curves

Gabion: A rectangular wire mesh cage filled with rock, which may be used to prevent erosion, or as a retaining wall.

Geotextile: A woven or nonwoven, water-permeable fabric generally made of synthetics such as polypropylene. It's used to slowly pass runoff or as bedding for rock to keep the rock separate from adjacent soil.

Grading: Earth-disturbing activities including excavation, cutting, filling, stockpiling, or any combination thereof.

Grubbing: Removing roots, stumps, or brush.

Infiltration: The gradual downward flow of water from the surface through soil to groundwater.

Intermittent Stream: A stream or portion of a stream that is dry for part of the year, ordinarily more than 3 months. It is delineated with dashed lines on USGS maps.

Lateral Migration: Channel erosion characterized by eroding outside bank and deposition on point bars so the cross section remains generally the same width and depth that moves laterally.

Low Flow (Base Flow): The stream flow sustained between runoff events. Its primary source is groundwater.

Micropool: A small pool area typically located near the outlet of a detention basin.

Observation Well: A test well in an infiltration trench to monitor water level and draining times.

Permeability: The capacity for transmitting runoff through a material or into soil. The relevant soil property is the saturated hydraulic conductivity, that is the amount of water that would move vertically through a unit of saturated soil per unit time under hydraulic gradient.

Perennial Stream: A stream that has continuous flow throughout the year.

Piping: Seepage and subsurface flow often causing removal of soil, eroding larger and larger pathways or "pipes."

Plunge Pool: A pool created at a weir or inlet to dissipate energy as water enters.

Pondscaping: A design of the contours, configuration, and plant structure of a stormwater wetland or pond. Plants are chosen with regard to water depths, duration of inundation, pollutant removal, and aesthetics.

Post Construction Stormwater Management Practices: Those practices designed for the treatment of stormwater pollutants and effects of runoff after construction is completed.

Porous Pavement: An alternative to conventional pavement whereby runoff is diverted through a porous asphalt layer and into an underground stone reservoir. The stored runoff then gradually infiltrates into the subsoil or an underdrain system.

Recurrence interval: Also known as the return period, it is the average period between precipitation events or flood events of a certain size based on the records and statistics.

Retrofit: The creation/modification of stormwater systems in developed areas through the construction of wet ponds, infiltration systems, wetland plantings, stream restoration, and other stormwater control techniques for improving water quality and creating aquatic habitat. A retrofit can consist of the construction of a new BMP in the developed area, the enhancement of an older stormwater management structure, or a combination of improvement and new construction.

Riparian Area: The transition region between flowing water and terrestrial ecosystems, which provides a continuous exchange of nutrients and woody debris between land and water. It generally includes not only the stream channel, but also flood plains and associated wetlands.

Riprap: Rock or stone placed over a bedding of geotextile, sand or gravel used to armor slopes against flowing water or wave action.

Saturated Hydraulic Conductivity: The amount of water that would move vertically through a unit of saturated soil per unit time under hydraulic gradient.

Sediment Pond: A sediment basin or sediment trap.

Settling Pond: Any pond used as a sediment basin or sediment trap.

Sheet Flow: Diffuse runoff flowing overland in a thin layer not concentrated and not in a defined channel.

Skimmer: An outlet designed so that the least turbid water is drawn from top of a sediment pond.

Soil Hydraulic Conductivity: The property describing permeability or the ability of water to move through soils, typically measured in saturated conditions (Ks).

Soil Stabilization: Vegetative or structural soil cover controlling erosion that includes permanent and temporary seed, mulch, sod, pavement, etc.

Stream: A system including permanent or seasonally flowing water, often with a defined channel (bed and bank), flood plain, and riparian ecosystem.

Streamway: The area of the stream corridor occupied or expected to be occupied by stream meanders.

Stormwater Treatment: The removal of pollutants from urban runoff and improvement of water quality, accomplished largely by deposition and utilizing the benefits of natural processes.

Topography: The relative slopes, positions and elevations of the landscape's surface.

Underdrain System: The drainage system utilized in bioretention and occasionally detention practices to maintain positive drainage.

Water Quality Volume: The extended detention volume captured for the purposes of treating pollutants and protecting stream stability downstream. This volume is prescribed by the Ohio EPA Construction General Permit.

Wet Pond: A conventional wet pond has a permanent pool of water. It also is called a retention pond and may or may not have the capacity of detention or peak-flow storage.

Wetland Bench: A level or gently sloping bench around the inside perimeter of a permanent pool that is less than 1 foot deep. Normally vegetated with emergent plants, the bench augments pollutant removal, provides habitat, conceals hash as water level drops, and enhances safety.

Appendix 9: Adjusting Hydrologic Soil Group for Construction

This appendix provides hydrologic soil group (HSG) values for undisturbed Ohio soils and predictable HSG values for Ohio soils that are altered by construction practices.

Hydrologic soil groups are used to assign a Curve Number (CN) when performing runoff calculations or in hydrologic models. Soil map units have been assigned to the four Hydrologic Soil Groups in technical resources and soil resources published by the USDA Natural Resource Conservation Service[1] (NRCS). NRCS HSG values are based on undisturbed, naturally-occurring soils. In contrast, soils at development sites are typically changed dramatically by construction practices that remove topsoil, change the soil profile and compact soils with heavy equipment. The runoff potential of a site is significantly impacted by these changes and should be reflected in hydrologic modeling and runoff calculations.

The following tables contain the HSGs and predicted HSGs for post-construction that were developed by applying the HSG criteria to modeled representative post-construction soil profiles. The modeled scenario consisted of the removal of the topsoil and subsoil to a depth of 18 inches and the compaction of the zone from 0 to 6 inches at the new surface. A fuller explanation of this process is available at the end of this appendix.

Soil Map Unit Component	HSG[1]	Post-Const HSG
Aaron	C	D
Abscota Variant (Warren)	A	No Eval.
Adrian	A/D	D
Aetna	B/D	D
Alexandria	C	D
Alford	B	D
Algansee	A/D	D
Algiers	B/D	D
Allegheny	B	C
Allegheny Variant (Belmont, Pike)	B	No Eval.
Allis	D	D
Alvada	B/D	D
Amanda	C	D
Amanda Variant (Licking)	B	No Eval.
Arkport	A	A
Ashton	B	D
Atlas	D	D
Aurand	C/D	D
Ava	C	D
Avonburg	D	D
Barkcamp	A	No Eval.

Soil Map Unit Component	HSG[1]	Post-Const HSG
Barkcamp (CL surface)	A	A
Barkcamp (L surface)	A	B
Beasley	C	No Eval.
Beaucoup	C/D	D
Belmore	B	C
Belpre	C	No Eval.
Bennington	C/D	D
Berks	B	D
Bethesda	C	D
Biglick	D	D
Birkbeck	B	D
Bixler	B	D
Blairton	C	No Eval.
Blakeslee	B/D	D
Blanchester	C/D	D
Blount	C/D	D
Bogart	B/D	D
Bogart Variant (Mahoning)	C	No Eval.
Bonnell	C	D
Bonnie	C/D	D
Bono	C/D	D

Notes: CL = clay loam; L = loam; substr = substratum; limestne substr = limestone substratum; Dual classes in Ohio, such as A/D, B/D, C/D are given for drained or undrained condition; No Eval. = No evaluation performed.

1. Hydrologic Soil Groups (HSGs) for Ohio (for undisturbed naturally-occuring sites) were updated in 2008 and should be used rather than HSGs from earlier publications (http://www.oh.nrcs.usda.gov/technical/soils/OH_hsg.pdf or contact the USDA Natural Resources Conservation Service in Columbus, Ohio). You may also utilize www.OhioERIN.com to find site specific HSG (unaltered).

Soil Map Unit Component	HSG[1]	Post-Const HSG
Boston	C	D
Boyer	A	B
Braceville	C/D	D
Brady	B	No Eval.
Bratton	C	D
Brecksville	D	D
Brenton	B	No Eval.
Bronson	B	No Eval.
Brooke	D	D
Brookside	C	D
Brookston	B/D	D
Broughton	D	D
Brownsville	A	D
Brushcreek	C	D
Calcutta	C/D	D
Cambridge	D	D
Cana	C	D
Cana Variant	C	No Eval.
Canadice	D	D
Canal	C/D	D
Caneadea	D	D
Canfield	C	D
Canfield (Summit)	D	D
Canfield Variant (Stark)	C	No Eval.
Captina	C	No Eval.
Cardinal	C/D	D
Cardington	C	D
Carlisle	A/D	D
Casco	B	A
Castalia	A	D
Cedarfalls	A	No Eval.
Celina	C	D
Celina Variant	C	No Eval.
Centerburg	C	D
Ceresco	A/D	D
Chagrin	B	C
Channahon	D	D
Chavies	A	B
Chenango	A	A
Chili	B	C
Cidermill	B	D
Cincinnati	C	D
Clarksburg	C	D
Claysville	C/D	D

Soil Map Unit Component	HSG[1]	Post-Const HSG
Clermont	D	D
Clifty	A	C
Clymer	B	C
Coblen	B	No Eval.
Cohoctah	A/D	D
Colonie	A	A
Colwood	B/D	D
Colwood (Erie)	C/D	D
Colyer	D	D
Colyer Variant	C	No Eval.
Condit	C/D	D
Conneaut	C/D	D
Conotton	A	C
Conotton Variant	A	No Eval.
Coolville	C	D
Corwin	C	D
Coshocton	C	D
Crane	B/D	D
Crider	B	No Eval.
Crosby	C/D	D
Crouse	B	No Eval.
Cruze	C	D
Cuba	B	C
Culleoka	B	D
Cyclone	B/D	D
Cygnet	B/D	D
Damascus	B/D	D
Damascus (Stark)	C/D	D
Dana	B	D
Darien	C/D	D
Darroch	B/D	D
Defiance	C/D	D
Dekalb	B	D
Del Rey	C/D	D
Del Rey Variant	C/D	D
Digby	B/D	D
Digby (till substr) (Wood)	C/D	D
Digby Variant (Auglaize, Putnam)	C/D	D
Dixboro	B/D	D
Doles	C/D	D
Donnelsville	B	No Eval.
Drummer	B/D	D
Dubois	C/D	D
Dunbridge	B	D

Notes: CL = clay loam; L = loam; substr = substratum; limestne substr = limestone substratum; Dual classes in Ohio, such as A/D, B/D, C/D are given for drained or undrained condition; No Eval. = No evaluation performed.

1. Hydrologic Soil Groups (HSGs) for Ohio (for undisturbed naturally-occuring sites) were updated in 2008 and should be used rather than HSGs from earlier publications (http://www.oh.nrcs.usda.gov/technical/soils/OH_hsg.pdf or contact the USDA Natural Resources Conservation Service in Columbus, Ohio). You may also utilize www.OhioERIN.com to find site specific HSG (unaltered).

Soil Map Unit Component	HSG[1]	Post-Const HSG
Duncannon	B	C
Dunham	B/D	D
Eden	D	D
Edenton	C	D
Edwards	C/D	D
Eel	B/D	D
Eel moderately deep	C/D	D
Eel Variant (Shelby)	C	No Eval.
Elba	C	D
Eldean	B	D
Elkinsville	B	D
Elliott	C/D	D
Ellsworth	C	D
Elnora	A/D	D
Endoaquents	D	D
Enoch	C	C
Ernest	C	D
Euclid	C/D	D
Fairmount	D	D
Fairmount Variant (Greene)	C	No Eval.
Fairpoint	C	D
Farmerstown	C	C
Faywood	C	D
Fincastle	C/D	D
Fitchville	C/D	D
Fitchville Variant	C/D	D
Flatrock	B/D	D
Flatrock (limestne substr)	B/D	D
Fluvaquents	D	D
Fox	B	D
Frankstown Variant	C	No Eval.
Fredericktown	B	No Eval.
Frenchtown	D	D
Fries	D	D
Fulton	C/D	D
Fulton (till substr)	C/D	D
Fulton Variant	C/D	D
Fulton (till substr)	C/D	D
Gageville	C/D	D
Galen	A/D	D
Gallia	B	C
Gallipolis	C	C
Gallman	B	C
Gasconade	D	D

Soil Map Unit Component	HSG[1]	Post-Const HSG
Gavers	C/D	D
Geeburg	D	D
Genesee	B	C
Genesee Variant (Ottawa)	C	No Eval.
Germano	B	D
Gessie	B	C
Gilford	A/D	D
Gilpin	C	D
Ginat	C/D	D
Glendora	A/D	D
Glenford	C/D	D
Glynwood	D	D
Glynwood (limestne substr) (Hancock)	C/D	D
Gosport	D	D
Granby	A/D	D
Granby (till substr)	A/D	D
Grayford	B	No Eval.
Gresham	C/D	D
Guernsey	C	D
Hackers	B	D
Haney	B	D
Hanover	C	D
Harbor	B/D	D
Harrod	C/D	D
Hartshorn	B	D
Hartshorn Variant (Monroe)	B/D	D
Haskins	C/D	D
Haubstadt	D	D
Haymond	B	C
Hayter	A	C
Hazleton	A	C
Hennepin	D	D
Henshaw	C/D	D
Henshaw Variant	C/D	D
Heverlo	C	No Eval.
Hickory	B	C
Holly	B/D	D
Holton	B/D	D
Homer	B/D	D
Homewood	C	D
Homeworth	B/D	D
Hornell	D	D
Houcktown	C/D	D
Hoytville	C/D	D

Notes: CL = clay loam; L = loam; substr = substratum; limestne substr = limestone substratum; Dual classes in Ohio, such as A/D, B/D, C/D are given for drained or undrained condition; No Eval. = No evaluation performed.

1. Hydrologic Soil Groups (HSGs) for Ohio (for undisturbed naturally-occuring sites) were updated in 2008 and should be used rather than HSGs from earlier publications (http://www.oh.nrcs.usda.gov/technical/soils/OH_hsg.pdf or contact the USDA Natural Resources Conservation Service in Columbus, Ohio). You may also utilize www.OhioERIN.com to find site specific HSG (unaltered).

Soil Map Unit Component	HSG[1]	Post-Const HSG
Hoytville Variant	C/D	D
Huntington	B	D
Hyatts	C/D	D
Ionia	B	No Eval.
Iva	C/D	D
Jenera	C/D	D
Jeneva	B	No Eval.
Jessup	C	D
Jimtown	B/D	D
Johnsburg	D	D
Joliet	D	D
Jonesboro	C	D
Jules	B	No Eval.
Kanawha	B	C
Kane	B/D	D
Keene	C	D
Kendallville	C	C
Kensington	B	C/D
Kerston	C/D	D
Kibbie	B/D	D
Killbuck	C/D	D
Kings Variant	C/D	D
Kingsville	A/D	D
Kinn	B	No Eval.
Knoxdale	B	No Eval.
Kokomo	C/D	D
Kyger	A/D	D
Lakin	A	A
Lamberjack	B/D	D
Lamson	A/D	D
Landes	A	A
Lanier	A	A
Latham	D	D
Latty	C/D	D
Latty (till substr)	C/D	D
Lawshe	D	D
Lenawee	C/D	D
Lenawee Variant	C/D	D
Leoni	A	No Eval.
Lewisburg	D	D
Library Variant	C/D	D
Libre	C	No Eval.
Licking	C	D
Lily	B	D

Soil Map Unit Component	HSG[1]	Post-Const HSG
Lindside	C	D
Linwood	B/D	D
Lippincott	B/D	D
Lobdell	C	D
Lockport	D	D
Lorain	C/D	D
Lordstown	C	D
Lorenzo	A	No Eval.
Losantville	D	D
Loudon	C	D
Loudonville	C	D
Lowell	C	D
Lucas	D	D
Lumberton	B	D
Luray	C/D	D
Luray Variant (Stark)	B/D	D
Lybrand	C	D
Lykens	C	D
Mahalasville	B/D	D
Mahoning	C/D	D
Marblehead	D	D
Marengo	B/D	D
Markland	C	D
Martinsville	B	D
Martisco	B/D	D
Martisco Variant (Logan)	C/D	D
McGary	C/D	D
McGary Variant	C/D	D
McGuffey	D	D
Mechanicsburg	B	C
Medway	C	D
Medway Variant	C	D
Medway (limestne substr)	B/D	D
Melvin	B/D	D
Mentor	B	D
Mermill	C/D	D
Mermill Variant	C/D	D
Mertz	C	C
Metamora	B/D	D
Miami	C	D
Miami Variant	C	No Eval.
Miamian	C	D
Miamian Variant	C	No Eval.
Milford	C/D	D

Notes: CL = clay loam; L = loam; substr = substratum; limestne substr = limestone substratum; Dual classes in Ohio, such as A/D, B/D, C/D are given for drained or undrained condition; No Eval. = No evaluation performed.

1. Hydrologic Soil Groups (HSGs) for Ohio (for undisturbed naturally-occuring sites) were updated in 2008 and should be used rather than HSGs from earlier publications (http://www.oh.nrcs.usda.gov/technical/soils/OH_hsg.pdf or contact the USDA Natural Resources Conservation Service in Columbus, Ohio). You may also utilize www.OhioERIN.com to find site specific HSG (unaltered).

Soil Map Unit Component	HSG[1]	Post-Const HSG
Mill	C/D	D
Millgrove	B/D	D
Millsdale	C/D	D
Milton	C	D
Milton Variant	C	No Eval.
Miner	C/D	D
Minoa	B/D	D
Mitiwanga	C/D	D
Mitiwanga Variant	D	D
Monongahela	D	D
Montgomery	C/D	D
Montgomery Variant (Pike)	D	D
Morley	D	D
Morley (limestone substr)	C	No Eval.
Morningsun	B	No Eval.
Morristown	C	C
Morrisville	C	No Eval.
Mortimer	C/D	D
Moshannon	B	D
Muck	B/D	D
Muse	C	D
Muskego	C/D	D
Muskingum	C	C
Nappanee	D	D
Negley	A	C
Neotoma	A	No Eval.
Newark	B/D	D
Newark Variant	B/D	D
Nicely	C	No Eval.
Nicholson	C	No Eval.
Nineveh	B	No Eval.
Nolin	B	D
Nolin Variant	B	No Eval.
Oakville	A	A
Ockley	B	C
Odell	C/D	D
Ogontz	B	No Eval.
Olentangy	B/D	D
Olmsted	B/D	D
Omulga	D	D
Opequon	D	D
Orrville	B/D	D
Orrville Variant (Richland)	A/D	D
Orrville Variant (Ashland)	C/D	D

Soil Map Unit Component	HSG[1]	Post-Const HSG
Oshtemo	A	A
Oshtemo (till substr)	A	C
Otego	B/D	D
Otisville	A	A
Ottokee	A	D
Ottokee (till substr)	A	No Eval.
Otwell	D	D
Pacer	B	No Eval.
Painesville	C/D	D
Pandora	C/D	D
Papakating	C/D	D
Parke	B	D
Parr	B	No Eval.
Pate	D	D
Patton	B/D	D
Patton Variant	B/D	D
Paulding	D	D
Pekin	D	D
Peoga	C/D	D
Perrin	A	No Eval.
Pewamo	C/D	D
Pewamo Variant	C/D	D
Philo	B	D
Pierpont	C	D
Pike	B	D
Pinegrove	A	A
Pinnebog	A/D	D
Piopolis	C/D	D
Plainfield	A	A
Platea	D	D
Plattville	C	No Eval.
Plumbrook	A/D	D
Pope	B	A
Princeton	B	B
Prout	C/D	D
Purdy Variant	C/D	D
Pyrmont	D	D
Ragsdale	C/D	D
Rainsboro	C	D
Rainsville	C	No Eval.
Ramsey	D	D
Randolph	C/D	D
Rarden	D	D
Raub	B/D	D

Notes: CL = clay loam; L = loam; substr = substratum; limestne substr = limestone substratum; Dual classes in Ohio, such as A/D, B/D, C/D are given for drained or undrained condition; No Eval. = No evaluation performed.

1. Hydrologic Soil Groups (HSGs) for Ohio (for undisturbed naturally-occuring sites) were updated in 2008 and should be used rather than HSGs from earlier publications (http://www.oh.nrcs.usda.gov/technical/soils/OH_hsg.pdf or contact the USDA Natural Resources Conservation Service in Columbus, Ohio). You may also utilize www.OhioERIN.com to find site specific HSG (unaltered).

Soil Map Unit Component	HSG[1]	Post-Const HSG
Ravenna	D	D
Rawson	D	D
Red Hook	B/D	D
Reesville	B/D	D
Remsen	D	D
Rensselaer	B/D	D
Rensselaer (till substr)	B/D	D
Richland	B	D
Riddles	B	C
Rigley	A	A
Rigley Variant	A	No Eval.
Rimer	A/D	D
Rimer (deep phase)	A/D	D
Risingsun	C/D	D
Ritchey	D	D
Rittman	D	D
Rockmill	B/D	D
Rodman	A	A
Rollersville	C/D	D
Romeo	D	D
Roselms	D	D
Ross	B	C
Ross Variant	D	D
Rossburg	B	D
Rossmoyne	C	D
Roundhead	C/D	D
Rush	B	D
Russell	B	D
Russell (bedrock substr)	B	No Eval.
Sandusky	B/D	D
Sarahsville	D	D
Saranac	C/D	D
Sardinia	B	D
Savona	B/D	D
Saylesville	C	D
Schaffenaker	A	D
Schaffer	C/D	D
Scioto	B	No Eval.
Sciotoville	C	D
Sebring	C/D	D
Sebring Variant	C/D	D
Secondcreek	C/D	D
Sees	C	D
Senecaville	C/D	D

Soil Map Unit Component	HSG[1]	Post-Const HSG
Seward	A	D
Sewell	A	No Eval.
Shawtown	B	No Eval.
Sheffield	D	D
Shelocta	B	D
Shinrock	C	D
Shinrock Variant (Henry)	C/D	D
Shinrock (till substr)	C/D	D
Shoals	B/D	D
Shoals (mod deep)	C/D	D
Shoals Variant	C/D	D
Sisson	B	D
Skidmore	A	C
Skidmore Variant	A	No Eval.
Sleeth	B/D	D
Sligo	B	No Eval.
Sloan	B/D	D
Sloan (mod deep)	B/D	D
Sloan Variant	B/D	D
Sloan (limestone substr)	B/D	D
Smothers	C/D	D
Spargus	B	No Eval.
Sparta	A	No Eval.
Spinks	A	A
Spinks (deep to limestone)	A	No Eval.
St. Clair	D	D
Stafford	A/D	D
Stanhope	B/D	D
Steinsburg	B	D
Stendal	B/D	D
Stone	C/D	D
Stonelick	A	B
Strawn	D	D
Stringley	A	No Eval.
Sugarvalley	B/D	D
Summitville	C	D
Swanton	B/D	D
Switzerland	B	No Eval.
Taggart	C/D	D
Tarhollow	C	D
Tarlton	C	No Eval.
Tedrow	A/D	D
Tedrow (till substr) (Wood)	C/D	D
Teegarden	C/D	D

Notes: CL = clay loam; L = loam; substr = substratum; limestne substr = limestone substratum; Dual classes in Ohio, such as A/D, B/D, C/D are given for drained or undrained condition; No Eval. = No evaluation performed.

1. Hydrologic Soil Groups (HSGs) for Ohio (for undisturbed naturally-occuring sites) were updated in 2008 and should be used rather than HSGs from earlier publications (http://www.oh.nrcs.usda.gov/technical/soils/OH_hsg.pdf or contact the USDA Natural Resources Conservation Service in Columbus, Ohio). You may also utilize www.OhioERIN.com to find site specific HSG (unaltered).

Soil Map Unit Component	HSG[1]	Post-Const HSG
Thackery	B	D
Thackery Variant	B	No Eval.
Thackery (till substr)	B/D	D
Thrifton	D	D
Tiderishi	C/D	D
Tilsit	D	D
Tioga	A	C
Tioga variant (Cuyahoga)	A	No Eval.
Tioga variant (Lake)	B	No Eval.
Tippecanoe	B	D
Tiro	C/D	D
Titusville	D	D
Toledo	C/D	D
Towerville	C/D	D
Trappist	C	D
Treaty	B/D	D
Tremont	C	D
Trumbull	D	D
Tuscarawas	C	No Eval.
Tuscola	C	D
Tuscola Variant	C	No Eval.
Tygart	C/D	D
Tyler	D	D
Tyner	A	A
Tyner Variant	A	No Eval.
Typic Udorthents	C	No Eval.
Uniontown	C	D
Upshur	C	D
Valley	D	D
Vandalia	C	D
Vandergrift	C/D	D
Vanlue	C/D	D
Vaughnsville	C	D
Venango	C/D	D
Vincent	C	D
Wabasha	C/D	D
Wabasha Variant	D	D
Wadsworth	D	D
Wadsworth Variant	D	D
Wakeland	B	No Eval.
Wakeman	B	No Eval.
Wallkill	B/D	D
Wallkill Variant	C/D	D
Wapahani	D	D

Soil Map Unit Component	HSG[1]	Post-Const HSG
Wappinger	B	No Eval.
Warners	C/D	D
Warsaw	B	C
Warsaw Variant	B	No Eval.
Watertown	A	A
Waupecan	B	No Eval.
Wauseon	A/D	D
Wauseon (deep to till)	A/D	D
Wayland	C/D	D
Waynetown	B/D	D
Wea	B	B
Wea Variant	B	No Eval.
Weikert	D	D
Weinbach	D	D
Wellston	B	D
Wernock	C	No Eval.
Wernock Variant	C	No Eval.
Westboro	C/D	D
Westgate	C	D
Westland	B/D	D
Westmore	C	D
Westmoreland	B	C
Wetzel	C/D	D
Weyers	A/D	D
Wharton	C	D
Wheeling	B	C
Whitaker	B/D	D
Wick	B/D	D
Wilbur	B	No Eval.
Willette	C/D	D
Williamsburg	B	C
Wilmer Variant	C	No Eval.
Woodsfield	C	C
Woolper	C	No Eval.
Wooster	C	D
Wyatt	D	D
Wynn	C	D
Xenia	C	D
Zanesville	C	D
Zepernick	B/D	D
Zipp	C/D	D
Zurich	C	No Eval.

Notes: CL = clay loam; L = loam; substr = substratum; limestne substr = limestone substratum; Dual classes in Ohio, such as A/D, B/D, C/D are given for drained or undrained condition; No Eval. = No evaluation performed.

1. Hydrologic Soil Groups (HSGs) for Ohio (for undisturbed naturally-occuring sites) were updated in 2008 and should be used rather than HSGs from earlier publications (http://www.oh.nrcs.usda.gov/technical/soils/OH_hsg.pdf or contact the USDA Natural Resources Conservation Service in Columbus, Ohio). You may also utilize www.OhioERIN.com to find site specific HSG (unaltered).

Hydrologic Soil Groups for Post-construction Soils

Overview

Hydrologic soil groups were created as a simple means to categorize inherent soil runoff potential and are commonly used to assign an appropriate Curve Number (CN) for hydrologic modeling purposes. Soil types have been assigned to hydrologic soil groups (HSG) in soil survey publications. In Ohio the HSGs are based on undisturbed, naturally occurring soils in an agricultural field or woodland setting. Soils properties at development sites are often changed dramatically by construction practices. Topsoil is removed, soil profiles are truncated or covered by grading activities, and exposed surfaces are compacted by heavy equipment traffic. The runoff potential is significantly impacted by these changes to the soil. This project predicts changes to HSG for soils that are altered by standard construction practices by applying the HSG criteria to modeled post-construction soil profiles.

Data for soil horizons from the USDA National Soil Information System (NASIS[1]) database were used to represent pre-construction profiles. From soil series with HSG = A, B or C, 150 soil series of significant extent in Ohio were selected for evaluation. A representative component was selected from official data sets for each series from commonly occurring map units. The standard construction practices were defined as: the removal of 18 inches of soil material from the top of the soil profile and the compaction of the zone from 0 to 6 inches at the new surface. To mirror the impact of the construction practices, layer depths in the component soil moisture table data were adjusted to reflect the removal of 18 inches (46 cm.) of soil. Similar adjustments were made to layer depths for the component soil moisture (water table) table and the component restrictions (impermeable layers) table. At the new surface, the top 6-inch (15 cm.) layer was modified in the component horizon table to show changes in infiltration caused by compaction at the surface. The USDA SPAW[2] tool was used to populate infiltration rates for the compacted soils utilizing pedon transfer functions. A report generator in NASIS was programmed to assign HSG criteria to each component. A comparison of the model's pre-construction to post-construction HSG values showed that most soils are downgraded by 1 or 2 HSG classes as a result of standard construction practices.

Methods

To calculate post-construction HSG, standard construction practices were defined as: the removal of 18 inches of soil material from the top of the soil profile and the compaction of the zone from 0 to 6 inches at the new surface.

In 2008, USDA-NRCS soil scientists in Ohio revised the HSG assigned to soil map unit data in their NASIS database. HSG were revised because of changes to Part 630 Chapter 7 of the National Engineering Handbook. Criteria for assignment of HSG was revised in Chapter 7. The published data had been compiled from manual calculations of soil profile data for each map unit. The previously published HSGs were computed on a component (soil series) basis, with representative groups based on the series typical pedon description and Soil Interpretation Record (old Soil 5 form) depths. For the revi-

1 Information regarding the USDA National Soil Information System (NASIS) database is available at http://soils.usda.gov/technical/nasis/index.html.

2 SPAW is a daily hydrologic budget model for agricultural fields and ponds developed by Dr. Keith Saxton, USDA-ARS (retired). This model includes a Soil Water Characteristics Hydraulic Properties Calculator, a program developed by Saxton and Dr. Walter Rawls USDA-ARS (retired) that can be used to estimate soil water tension, conductivity and water holding capability based on soil texture, organic matter, gravel content, salinity, and compaction. The model is available at: http://hydrolab.arsusda.gov/SPAW/Index.htm (site last updated on Oct 29, 2009).

sion, they used a report generator that calculated HSGs from published soil layer data. A large number of map units had different groups when calculated with the report generator than what had been published in the official data set. The report generator, which uses the criteria from Chapter 7 of Part 630 NEH, is run on soil map units, not components (series). Because of variation in depth to restrictive features, similar map units could receive different HSG by using the report generator. The differences in HSGs were due to changes in criteria in addition to variations between map units of the same component. In 2008 and 2009, NRCS edited their official data to show the revised HSG values. From the revised HSG values, soil components (series) with HSG = A, B or C, 150 soil series of significant extent in Ohio were selected for evaluation.

Soil component data is published by county soil survey areas in Ohio. To reflect regional variations in soil properties for a single named component, each county's component data set is unique for the occurrence of that soil type in that county – and in some counties, the component data is unique for each occurrence in a map unit. For a single component soil type named, the statewide database may contain a few, several or many unique data sets. An effort was made to select a representative component data set for each component by reviewing map unit characteristics. Map unit extent and distribution was evaluated. Preference was given to map units with larger acreage and to map units centrally located to the geographic distribution.

Layer depths in the component horizon (CH) table data were adjusted to reflect the removal of 18 inches (46 cm.) of soil. Any layer where bottom depth is less than or equal to 46 cm was deleted. Any layer where the bottom depth was greater than 46 cm and the top depth was less than 46 cm, the top depth was set at 0 cm. and 46 cm. was subtracted from the bottom depth. If the resulting layer was less than 6 cm. thick, it was deleted and the top depth of the next lowest layer was set at 0 cm. Where top depth greater than 46 cm, 46 cm was subtracted from both top and bottom depth.

The depth of two soil features that influence HSG are tracked independently of the CH table: soil water tables and soil restrictive features. Depth to soil water tables is stored in the component soil moisture (CSM) table and depth to restrictive features is stored in the component restrictions (CR) table. In both tables, top and bottom layer depths for all layers were edited by subtracting 46 cm, and values less than 0 cm edited as 0 cm.

Layer depths and Ksat values in the CH table data were adjusted to reflect creation of a 6 in. (15 cm.) zone of compacted surface during construction. If the thickness of the surface layer of the cut-soil was less than or equal to 25 cm the entire layer was used to represent the compacted zone. If it was greater than 25 cm, the upper 15 cm was replicated and modified to show compaction. The surface layer of the cut soil was copied and pasted above the original layer. The depths of the pasted layer were set at top equal to 0 cm and bottom equal to 15 cm. The top depth for the copied layer was set at top equal to 15 cm.

The USDA-ARS pedon transfer function tool 'SPAW' was used to calculate the Ksat values for the compacted surface. Ksat low range values were calculated using high clay percent and low sand percent and gravel percent; and conversely Ksat high values were calculated using low clay percent and high sand and gravel percent. Organic matter and salinity were assumed to be 0 percent. The compaction level was set at 'dense' resulting in a 110 percent compaction value.

Data used in the post-construction calculations for HSG values can be viewed in NASIS.

Load data from Area Type equal to Ohio Urban; Area equal to Ohio Urban Land; and Area Symbol equal to OHUL. Legend status equal to 'non-project'. An edit setup in the MO13 directory named "Marietta Urban" was created to view layer data that was edited in the post-construction data map units. The standard report named "EXPORT HSG data;" in the MO11 Directory was used to generate HSGs.)

Site Data

As a companion project to the development of the post-construction data set for NASIS, ODNR-DSWC soil scientist planned to gather soil profile descriptions for post-construction soils. The goal was to see how accurately the standard construction practices, as defined in our model (the removal of 18 inches of soil material from the top of the soil profile and the compaction of the zone from 0 to 6 inches at the new surface), matched actual site data gathered from the field.

Urban sites and soil types were identified for sampling. In the field, site disturbances from construction practices were verified and profile descriptions were taken from small hand-dug pits. When site conditions permitted, adjacent, undisturbed soils were also described. The extent of sampling was curtailed by staff reductions that occurred during the project.

From 13 sites, 24 profile descriptions were collected: 14 descriptions were classified as 'post-construction' and the remaining 10 descriptions were natural soils adjacent to the construction sites. The post-construction soils were judged to be cut profiles at 4 sites; fill profiles at 9 sites and 1 site was undetermined. Compaction was evaluated at the sites with a hand held penetrometer and by physical observations. At most sites compaction was rated severe in at least one horizon. The compacted horizon was not always the surface horizon.

Appendix 10: Alternative Pre-treatment Options for Dry Extended Detention Basins - Rationale and Expectations

Research has shown that of the various mainstream stormwater BMPs (wet ponds, dry ponds, media filters, bioretention, wetlands), the suspended solids removal efficiency of dry ponds is the lowest or worst. The National Pollutant Removal Performance Database for Stormwater Treatment Practice, 2nd Edition (Center for Watershed Protection, 2000) reports the median TSS removal efficiencies for end-of-pipe controls as shown in the table below. Because of their poor water quality performance, several states no longer allow the use of dry ponds.

BMP	Median TSS Removal (%)
Dry Pond	47
Wet Pond	80
Stormwater Wetland	76
Filtering Practices	86
Infiltration Practices	95

Table 1. Median total suspended solids removal efficiences (CWP, 2000).

Ohio EPA has been interested in providing the most flexibility/options to the site designer but, with a 80% TSS removal target, the traditional dry pond designs fall short. Forebays have been shown to be effective pretreatment for all types of end-of-the-pipe stormwater BMPs, improving performance numbers significantly. A WinSLAMM (Source Loading And Management Model) analysis using solely the required 0.1*WQv volume would allow a wet pool forebay to remove upwards of 50% of the annual TSS load from most development types. Needless to say, such a forebay would significantly improve the water quality performance of dry basins.

Ohio EPA and ODNR-DSWR recognize there may be sites where, because of concerns about standing water (e.g. for safety reasons), the designer needs alternatives to a dry basin having wet pool forebays and micropools.

Figure 1. "Dry" extended detention pond with a forebay and a micropool (near the dam and the outlet).

First, the designer should consider whether the WQv requirement can be met through the use of other structural BMPs such as bioretention or pervious pavement. Bioretention ponds water only briefly and shallowly, and would not create the same perceived threat as wet forebays and micropools. Pervious pavement does not pond water at the surface. If these BMP alternatives can be used to meet the WQv requirement, a dry basin without permanent pools can still be used to meet local peak discharge requirements.

A site can usually be divided into smaller drainage areas for WQv requirements. Bioretention works extremely well for small drainage areas, and often parking lot islands or landscape requirements may offer the needed locations/ area. If these BMP alternatives are deemed unsuitable for the site, the alternative dry basin design used to meet the WQv requirement must show performance and maintainability equivalent to a dry basin with forebay and micropool. The key considerations to address would be:

- pretreatment of runoff such that 50% of the annual TSS load is removed before discharge enters the dry basin;
- the outlet design allows for long-term function of the extended detention volume with minimal maintenance and oversight.

Page updated on 11-27-12

Pretreatment Options

> **Both filter strips and grass channels provide "biofiltering" of stormwater runoff as it flows across the grass surface. However, by themselves these controls cannot meet the 80% TSS removal performance goal. Consequently, both filter strips and grass channels should only be used as pretreatment measure or as part of a treatment train approach.**
>
> **(*Georgia Stormwater Management Manual*, Page 3.1-3)**

Water quality pre-treatment is provided through practices that slow, spread, filter and/or infiltrate water along its flow path. The needed level of pretreatment can be attained by using a "treatment train" approach, i.e., combining practices such as impervious area disconnection, grass filter strips, and grass swales. Another strategy is to focus these practices on treating runoff from pollutant hot spots such as parking areas driveways and roads. Our observations suggest these opportunities exist on almost every site, in-spite of the engineer's or developer's initial concerns about space limitations.

Preliminary parking lot runoff modeling results using WinSLAMM show that disconnecting the parking lot from the storm sewer system (i.e., placing all storm drain inlets in vegetated/ grassed collection areas with a minimum 15 ft travel distance from the parking lot) reduce both the annual runoff volume and load of total particulate solids by about 25%[1].

Figure 2. Disconnecting parking and storm sewers in order to reduce pollutant loads.

Grass swales can be designed to remove upwards of 50% of total solids. To provide the desired water quality treatment, the design requires attention to flow depths and residence times for the water quality event, and maintaining flow velocities that prevent erosion and resuspension.

Guidance for these practices is available in the Rainwater and Land Development Manual. In addition, the Iowa Stormwater Manual provides more detailed calculations for sizing/ designing filter strips (Section 21-4) and grass swales (Section 21-2) to meet water quality targets. The Georgia Stormwater Manual and Lake County, Ohio, Swale Guidance are other useful design references.

One alternative is to incorporate the pretreatment options noted above into the design of the basin itself. The resulting basin will look more like a low, wide swale than the traditional deep-sided detention basin, and can often times be incorporated into the lawn and landscaping of the site (see figure 3).

Figure 3. Disconnecting parking and storm sewers in order to reduce pollutant loads.

1 WinSLAMM, Dayton 1991 rainfall, 1 Ac parking lot, clay soil

Page updated on 11-27-12

For in-basin pre-treatment, the following minimum requirements may be used as a substitute for a forebay and micropool:

- flow length resulting in a minimum residence time of 5 minutes above the top of the WQv (figure 4)
- max flow depth of 4” (0.33 ft)
- use manning’s n=0.15
- for HSG C&D soils, an under drain should be used to help maintain appearance and function
- designs should ensure stability (i.e., maintain flows less than max velocity) for soil, grass mix and method of establishment
- an outlet that is protected from clogging (figure 5)
- storm drain outfalls should be properly designed for stability and energy dissipation.

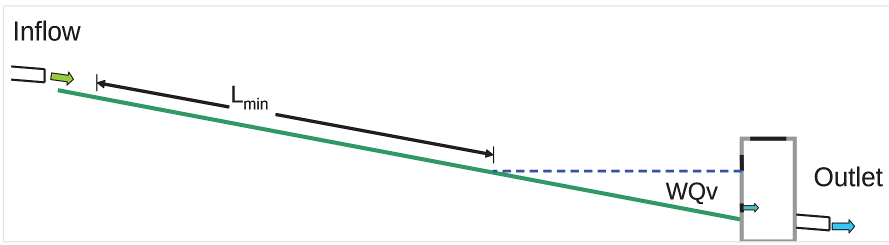

Figure 4. Alternative vegetative pre-treatment requires a flow length that allows a minimum of 5 minutes residence time above the water quality volume.

Outlet Protection

Incorporating a permanent micropool into a dry basin design allows the use of a reverse slope outlet pipe in addition to enhanced water quality treatment. The advantage of the reverse slope pipe is that it moves the pipe entrance below the water surface protecting it from floatable debris (bottles, bags, styrofoam, leaves, etc.) that commonly blocks small (less than 4”) outlet openings at the water surface (see photos).

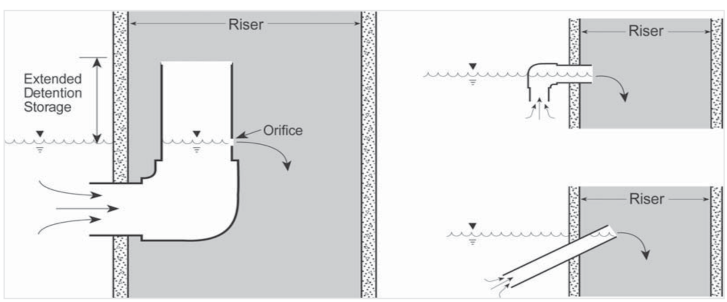

Figure 5. Reverse Slope Outlets

Figure 6. Unprotected Dry Basin Outlets

When eliminating the micropool from a WQv dry basin design, an alternative protected outlet design must be used. The protection comes from removing the controlling orifice inside the catch basin, and using a perforated lateral (or riser) and gravel filter to block any floatable materials (see the figure and photo).

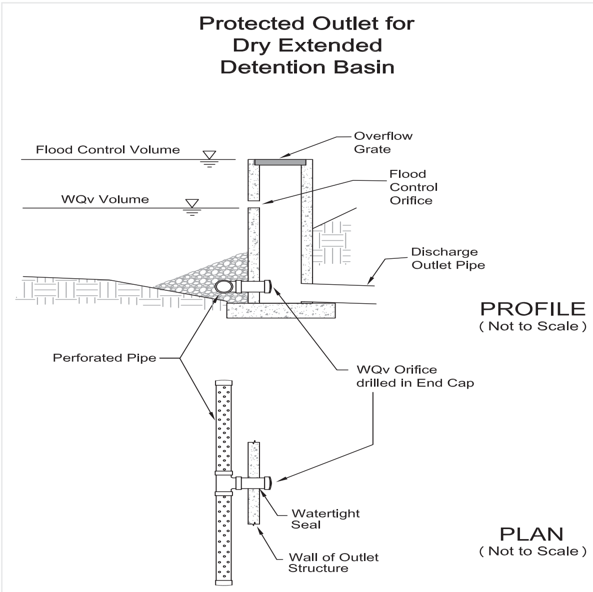

Figure 7. Protected Basin Outlets

Conclusion/Recommendation

There may be situations where a dry basin with: permanent pool forebay and micropool is not an option. In these situations, the designer should first consider alternative BMPs (bioretention, enhanced swales and/ or pervious pavement) for meetjng the WQv requirement.

Pre-treatment and outlet protection options are available that will provide equivalent performance to forebays and micropools. The designer must follow guidance to ensure that performance and maintenance goals are met.

Reference

Biohabitats. 2006. Swale Guidance, Lake County Stormwater Management Department.

CTRE. 2008. Iowa Stormwater Management Manual. Center for Transportation Research and Education, Iowa State University, Ames.

CWP. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practice, 2nd Edition. Center for Watershed Protection, Ellicott City, MD.

Haubner, S. (Editor). 2001. Georgia Stormwater Management Manual, Volume 2 - Technical Handbook. Atlanta Regional Commission.

Appendix 11: Critical Storm Method

The Critical Storm Method is a criteria recommended for controlling the peak discharge of stormwater from larger storm events (1 - 100 yr recurrence interval). It is recommended to protect property from flood damage and channel erosion, and to protect water resources from degradation resulting from accelerated stormwater flows.

In Ohio, most peak discharge control regulations reside in the requirements of a municipal, township or county government or in a stormwater . While the state of Ohio recommends the use of the Critical Storm Method for peak discharge control, actual requirements will vary according to what each community has adopted locally in conjunction with Ohio EPA NPDES permit requirements. This method has previously been included in the Ohio Stormwater Control Guidebook (ODNR, 1980), ODNR-DSWR model regulations and standards to prevent stream channel and floodplain erosion (Ohio Revised Code 1501:15-1-05).

Important Considerations

The use of this or other stormwater management criteria should assume certain conditions for adequate design, construction and continued function of stormwater management practices:

(1) Stormwater management systems must be designed for the ultimate use of the land. Areas developed for subdivisions must provide a stormwater management system for the ultimate plan of development for all of the subdivided lots.

(2) Stormwater management facilities and facilities must be designed so that they will continue to function with the least maintenance necessary.

(3) Stormwater management facilities should be designed to meet multiple objectives as much as possible. For instance pollution control, downstream channel stability, flood control, runoff reduction, and aesthetic quality are sample objectives.

(4) Stormwater management facilities and facilities shall be designed with specific regard to safety.

(5) The design criteria shall be applied to each watershed within the development area. All pre- and post-development runoff rates and volumes shall be calculated using their respective drainage divides.

The Critical Storm Method

A) In order to control pollution of public waters by soil sediment from accelerated stream channel erosion and flood plain erosion caused by accelerated stormwater runoff from development areas, the peak rates of runoff from an area after development may be no greater than the peak rates of runoff from the same area before development for all twenty-four-hour storms from one- to one-hundred-year frequency. Design and development to match the peak rate of runoff for the one, two, five, ten, twenty-five, fifty, and one-hundred year storms may be considered adequate to meet this rule.

(B)

(1) If the volume of runoff from an area after development will be greater than the volume of runoff from the same area before development, it shall be compensated by reducing the peak rate of runoff from the critical storm and all more-frequent storms occurring on the development area to the peak rate of runoff from a one-year frequency, twenty-four-hour storm occurring on the same area under predevelopment conditions. Storms of less-frequent occurrence (longer return periods) than the critical storm up to the one-hundred-year storm shall have peak runoff rates no greater than the peak runoff rates from equivalent size storms under predevelopment conditions.

(2) The critical storm for a specific development area is determined as follows:

(a) Determine the total volume of runoff from a one-year frequency, twenty-four-hour storm, occurring on the development area before and after development.

(b) From the volumes in paragraph (B)(2)(a) of this rule, determine the per cent of increase in volume of runoff due to development and, using this percentage, select the critical storm from this table:

If the percent of increase in runoff volume is		The critical storm for peak rate control will be
equal to or greater than	and less than	
-	10	1 year
10	20	2 year
20	50	5 year
50	100	10 year
100	250	25 year
250	500	50 year
500	-	100 year

Table 1-1 Critical storm determination using percent of increase in runoff volume.

(C) Methods for controlling increases in stormwater runoff peaks and volumes may include but are not limited to:

(1) Retarding flow velocities by increasing friction; for example, grassed road ditches rather than paved street gutters where practical, discharging roof water to vegetated areas, or grass and rock-lined drainage channels.

(2) Grading and use of grade control structure to provide a level of control in flow paths and stream gradients.

(3) Induced infiltration of increased stormwater runoff into the soil where practical; for example, constructing special infiltration areas where soils are suitable, retaining topsoil for all areas to be vegetated, or providing good infiltration areas with proper emergency overflow facilities.

(4) Provisions for detention and retention; for example, permanent ponds and lakes with stormwater basins provided with proper drainage, multiple-use areas for stormwater detention and recreation, wildlife, or transportation, or subsurface storage areas.

Reference: Goettemoeller, R.L., D.P. Hanselmann, and J.H. Bassett. 1980. Ohio Stormwater Control Guidebook. Ohio Department of Natural Resources, Division of Soil and Water Districts, Columbus. http://www.dnr.state.oh.us/soilandwater/water/urbanstormwater/default/tabid/9190/Default.aspx