INVER GROVE HEIGHTS
NWA

Chapter 8

Details of Stormwater Best Management Practices (BMPs)

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

Details of Stormwater Best Management Practices (BMPs)

Chapter 8

Key Topics: guidance materials for recommended BMPs, BMP fact sheets, BMP guidance documents, and design factors

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I. Introduction

Stormwater BMP design is governed by two fundamental influences: regulatory compliance and technical performance. This manual has taken design procedures recommended in the Minnesota Stormwater Manual and customized them to reflect the unique conditions of the NWA and the focus on infiltration in this landlocked basin system.

II. Fact Sheets and Design Guidance - General

The fact sheets and design guidance document information is presented in treatment train order:

Pollution Prevention

- ► Residential Practices Fact Sheet
- ► Municipal Practices Fact Sheet
- ► Industrial & Commercial Practices Fact Sheet

Better Site Design

- ► Overview Fact Sheet
- ► Residential Streets and Parking Lots Fact Sheet
- ► Lot Development Fact Sheet

Temporary Construction Erosion and Sediment Control

- ► Fact Sheet

Green Roofs

- ► Fact Sheet
- ► Guidance Document

Pervious Surfaces

- ► Fact Sheet
- ► Guidance Document

Rainwater Harvesting

- ► Fact Sheet
- ► Guidance Document

Bioretention Practices

- ► Fact Sheet
- ► Guidance Document

Filtration Practices

- ► Fact Sheet
- ► Guidance Document

Infiltration Practices

- ► Fact Sheet
- ► Guidance Document

Stormwater Ponds

- ► Fact Sheet
- ► Guidance Document

Stormwater Wetlands

- ► Fact Sheet
- ► Guidance Document

Supplemental BMPs

- ► Filtration Devices Fact Sheet
- ► Hydrodynamic Devices Fact Sheet
- ► Chemical & Biological Treatment Fact Sheet

Soil Amendments

- ► Fact Sheet
- ► Guidance Document

The two-page fact sheets can be used as stand-alone education pieces or as introductions to the more detailed design guidance sheets. These summary fact sheets present a description of the BMP, plus overview information on suitability, key design considerations (benefits and limitations), performance information, and site factors. Additional design Guidance Sheets are presented for the structural BMPs (Green Roofs, Rainwater Harvesting, Pervious Surfaces, Bioretention Practices, Filtration Practices, Infiltration Practices, Stormwater Ponds, Stormwater Wetlands and Soil Amendments). Each section of design guidance consists of discussions of BMP suitability, major design elements, design procedures, O&M procedures, cost determinations, graphics and references.

III. NWA Design Influences

Stormwater BMP design is governed by two fundamental influences: regulatory compliance and technical performance. This manual has taken design procedures recommended in the Minnesota Stormwater Manual and customized them to reflect the unique conditions of the NWA and the focus on infiltration in this landlocked basin system.

Regulatory

Minimum stormwater management requirements for most new construction are specified at the state level by the MPCA General Stormwater Permit for Construction Activities (MNR100001), often referred to as the construction general permit. For the NWA, additional requirements are outlined in the NWA Planned Unit Development (PUD) Overlay District and in Inver Grove Heights City Code, (Section 430 - Storm Water Management). Design criteria specifically required by City Code, the PUD or MPCA Permit are identified in the text of the following sections with the term REQUIRED. Of course, if the indicated rule does not apply in a given situation, neither do the associated requirements.

City Code, the PUD and the MPCA construction general permit allow specific permanent stormwater management BMPs. The focus in the NWA is on infiltration/filtration areas, but there may be circumstances requiring wet detention or regional ponds. These BMPs must meet the design requirements found in these

RESOLVING DESIGN CONFLICTS

When designing a BMP, it is possible that the site conditions will lead to conflicting regulatory or technical requirements. Designers and regulators that find themselves in such a situation should use the following guide to resolve these conflicts:

REQUIREMENT vs. REQUIREMENT: Contact local water management authority to discuss solutions. Usually the strictest requirements will satisfy both regulations.

REQUIREMENT vs. TECHNICAL RECOMMENDATION: Follow regulatory requirement.

TECHNICAL RECOMMENDATION vs. TECHNICAL RECOMMENDATION: Use best professional judgment in consultation with local authorities.

documents. Alternative stormwater treatment BMPs are allowed if they can demonstrate by calculation, design, or other independent methods that they will achieve approximately 85% removal of total suspended solids on an annual average basis. The removal efficiency should be based on all particle sizes from the Midwest particle size distribution found in the National Urban Runoff Program (NURP) pond study completed in 1983. The permit application REQUIRES the submission of a Storm Water Management Plan which includes a mitigation plan, monitoring requirements, and performance goals for the proposed BMP, specifically:

- Existing site map showing topography and delineating water bodies at the site
- Site construction plan indicating erosion and sediment control measures and construction sequencing
- Calculations, plans, and specifications
- A description of the drainage area tributary to the alternative BMP
- Mitigation plan for replacement of the alternative BMP in the event that the monitoring plan show that the BMP fails to remove 85% of the Total Suspended Solids on an annual average basis from the site runoff.
- Final Site plan including landscaping and drainage plans
- Post construction monitoring plan

It must be understood that **additional local, state, or federal regulations may apply to a particular stormwater management practice**, although they are not specifically indicated in this Manual. These additional requirements must be identified and satisfied in all BMP construction projects.

Technical

In addition to the requirements outlined in applicable regulations, there are technical or engineering principles that are not specified in code but which can significantly affect BMP performance. Within this category of non-stipulated, performance-based design principles, a further distinction may be made between *essential design standards*, identified in this Manual with the term HIGHLY RECOMMENDED, which are critical for proper functioning, and *design recommendations*, identified as RECOMMENDED, which are valuable for enhancing BMP performance but not strictly crucial to the design.

IV. Design Guidance - Overview

BMP Suitability

This first section contains general suitability information for each BMP and its role in the treatment train. Information includes major features of each BMP "variant" or practice variation. In addition to the typical design elements, this guidance includes discussions of cold climate design modifications, retrofit feasibility, water quantity and water quality treatment, and limitations of the practice.

Design Elements

Site conditions often dictate the selection of BMPs. Therefore, this section allows site owners and designers to conduct a preliminary screening to learn if the BMP is feasible, based on specific site conditions. Major design elements of each BMP are described.

Construction Details and Specifications

Typical details for each structural BMP, and some variants, are included as AutoCAD Version 2000 DWG file format in Appendix A. Each document includes plan and profile views, plus important details, such as inlet structures, cross-sections and outlet structures. The notes section includes information that designers should consider incorporating into their technical specifications. Designers are encouraged to research other excellent water resources related design documents prepared by Minnesota agencies:

Supplemental Environmental Design Documents for Public Watercourse Crossings, June, 2005
Minnesota Department of Natural Resources

CADD Standards, Minnesota Department of Transportation
CADD Standards Software Libraries
Mn/DOT Standard Plans, English Subject Index - Mn/DOT

Mn/DOT Standard Specifications for Construction
Mn/DOT Standard Specifications for Construction - 2000 and 1995 (Metric) Editions

*Mn/DOT Drainage Manua*l, 2005
Hydraulics External Home

Mn/DOT Specifications for Erosion Control (draft)
Office of Environmental Services

Erosion Control Handbook for Local Roads, 2003. Minnesota Local Technical Assistance Program (LTAP)

Best Practices Handbook on Roadside Vegetation, 2000. Minnesota Local Technical Assistance Program
Publications - Minnesota LTAP

Plants for Stormwater Design, Minnesota Pollution Control Agency
Plants for Stormwater Design -- Minnesota Pollution Control Agency

Operation and Maintenance

Long term performance of BMPs is ensured with proper operation and regular maintenance. Therefore, it is REQUIRED that site designers communicate how to maintain the BMP in an Operation and Maintenance (O&M) Plan. Owners and maintenance staff will be able to reference this plan when they have questions about sediment removal, valve operation, or capacity for future site expansion. Contents of an O&M

plan could include: as-built plans, operating instructions for weirs and valves, vegetation list, vegetation maintenance schedule, and maintenance checklists.

In this section operation and maintenance is discussed in terms of phasing:

- Design Phase Maintenance Considerations
- Construction Phase Maintenance
- Post-Construction Operation and Maintenance

Suggested checklists for construction phase maintenance and post-construction phase O&M are contained in Appendix D.

Construction and Maintenance Costs

The cost considerations section of the Guidance Sheets are set up to guide users through developing a cost to construct, operate and maintain the BMPs selected for their sites. A detailed cost estimation procedure, including both construction and O&M costs, is contained in the design guidance. A design elements table includes major features of the specific BMP. The list does not include construction activities that are common to all aspects of a construction project, such as mobilization, traffic control and site erosion and sediment control. Estimators are encouraged to include these items for BMP construction projects that are not associated with a larger site development or redevelopment project. The worksheets contained in Appendix F can also be used to prepare a detailed cost estimate.

Design Procedures

Detailed design guidance for each BMP includes step by step procedures. The steps refer the designer back to better site design procedures in Chapter 4 so that the space dedicated to stormwater management within any site is optimized for both location and size. Designers are encouraged to fit a stormwater practice into the space available, and then check the hydraulics to determine if the size is adequate for managing the volume associated with the 5-year 24-hour rainfall event. This procedure is purposely intended to optimize the space available for BMPs on each site.

Figure 8.1 lays out the general procedural steps recommended in this manual. Specific steps, based on this general procedure, are detailed in the design guidance sheets.

V. The Role of Pre-Treatment

Many of the stormwater practices discussed in this manual require pre-treatment as described in Chapter 7. The reason for this requirement is the necessity to keep a BMP from being overloaded, primarily by sediment, and the protection of groundwater resources from pollution. Pre-treatment can also be used to dampen the effects of high or rapid inflow, dissipate energy, and provide additional storage. All of these ancillary benefits help BMP performance.

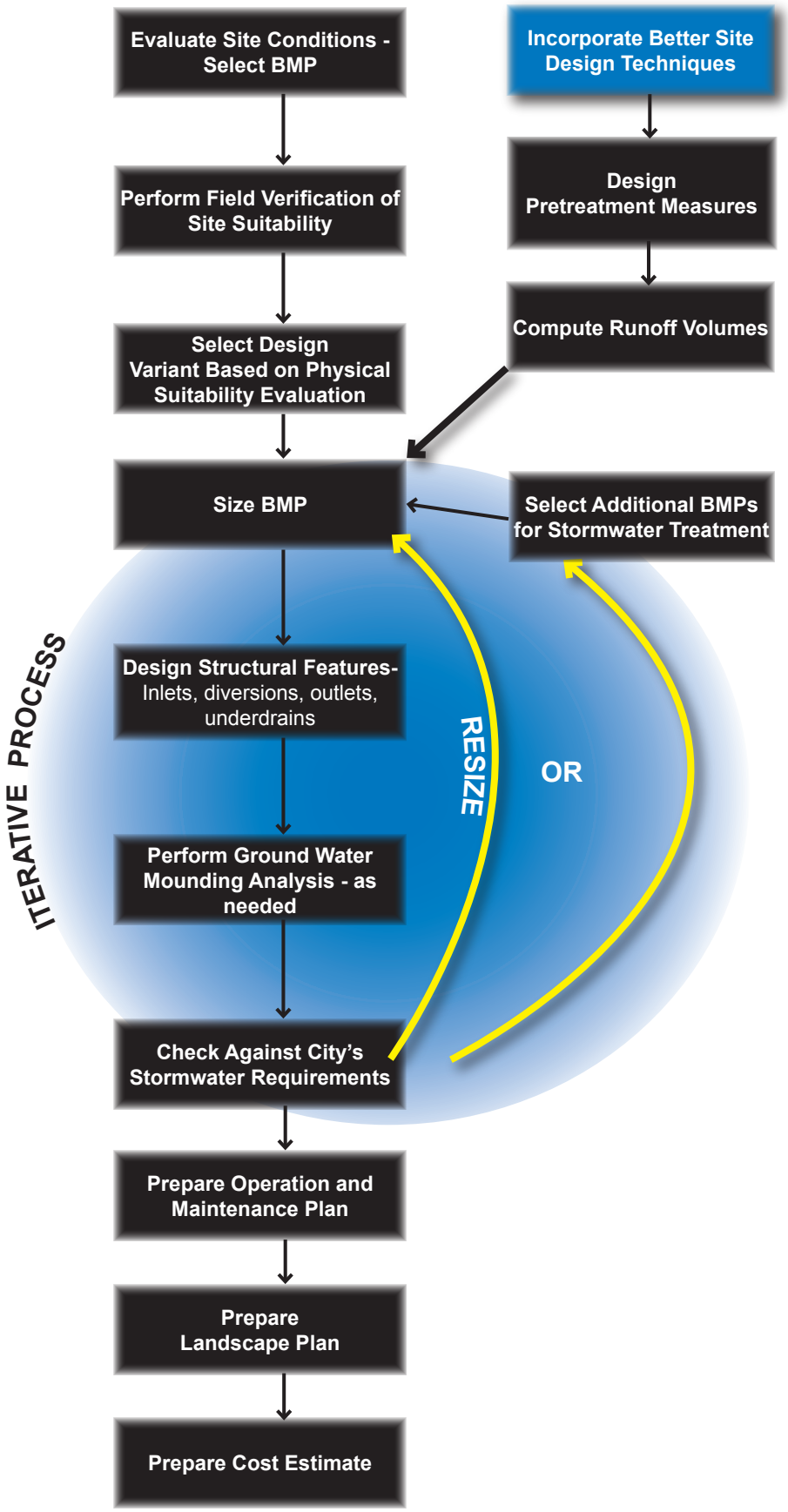
Methods of Pre-Treatment

There are many ways to pre-treat runoff prior to discharging it into an infiltration BMP including:

- Forebays – settle sediments from water before further treatment in stormwater pond
- Small sediment basins – settle sediment from water before further treatment by another BMP
- Street/parking lot sweeping – remove pollutants from an impervious surface draining to a BMP
- Proprietary settling/swirl chambers – remove particulates and litter prior to a BMP

Although “pre-treatment” does not appear as a BMP group in this chapter, many of the listed BMPs can perform in such a role.

Figure 8.1 Design Procedures Flowchart



VI. The Importance of Maintenance

Over time, watershed organizations, homeowner associations and municipalities have learned that 20 years of ignoring routine maintenance can lead to expensive rehabilitation projects. The lesson learned for stormwater ponds is that “low maintenance” does not mean “no maintenance”. Now that there are a number of successful alternatives to stormwater ponds, the pond maintenance lessons become even more important. Smaller BMPs will require a more frequent maintenance cycle, and native vegetation will require care to prevent invasion of non-native plant species.

The BMPs contained in this manual are recommended because each has been proven effective in the removal of pollutants from stormwater runoff. Long term effectiveness of all BMPs requires the regular removal of these accumulated pollutants to ensure capacity for ongoing pollutant removal. The *Stormwater Pond and Wetland Maintenance Guide* (CWP, 2004) describes a life cycle for ponds and wetlands that could apply to all structural BMPs.

Maintenance is necessary to prevent the following problems (CWP, 2004):

- Sediment accumulation, reduction in storage volume
- Debris blockage of structures
- Structural damage
- Invasive plants
- Loss of slope stabilization vegetation
- Reduced structural integrity of embankments, weirs or risers

This chapter includes detailed maintenance recommendations, check lists and cost information.

VII. Fact Sheets

These two-page fact sheets can act both as stand alone general education materials or as introductions to more detailed design guidance. Fact sheets present a general description of the BMP and overview information on suitability, key design considerations such as benefits and limitations, performance information, and site factors. For BMPs requiring more detailed design work, the fact sheets are supplemented with a narrative section providing more in depth guidance to the designer.

Fact sheets alone are provided for the following planning level BMPs and also in the case of Supplemental BMPs, where detailed design guidance is provided by the proprietor of these devices.

- Better Site Design
- Pollution Prevention
- Temporary Construction Sediment and Erosion Control
- Supplemental Best Management Practices

Supplemental guidance documentation, in addition to the stand alone fact sheets, is provided for the following BMPs:

- Green Roofs
- Rainwater Harvesting
- Pervious Surfaces
- Filtration
- Bioretention
- Infiltration
- Stormwater Ponds
- Stormwater Wetlands
- Soil Amendments

RESIDENTIAL PRACTICES

Eagle Valley - Woodbury, MN

Definition:
Residential pollution prevention practices are household and neighborhood activities that prevent or reduce the contamination of stormwater.

KEY CONSIDERATIONS

Description:
Residential pollution prevention practices prevent or reduce stormwater contamination from residential sources such as yards, driveways, sidewalks, and household products. These practices are often simple, low cost behavioral changes that improve subwatershed water quality by minimizing the introduction of pollutants including sediment, nutrients, metals, bacteria, trash, oil, and toxins. Each of these practices are highly suitable and effective in cold climates. Table 8.1 indicates the pollutants controlled by various residential pollution prevention practices while Table 8.2 describes some of the methods used for each of these practices. See Photo Credits and References for further information.

Table 8.1 Residential Practices Pollutant Controls

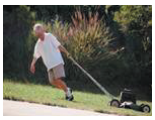
Practice	Stormwater Pollutants Controlled						
	Sediment	Nutrients	Metals	Bacteria	Trash	Oil	Toxins
Fertilizer and Pesticide Management	○	●	○	○	○	○	●
Litter and Animal Waste Control	○	●	○	●	●	○	○
Yard Waste Management	◑	●	○	◔	◔	○	○
Household Hazardous Waste Control	○	◔	●	○	○	●	●
Alternative Product Use	○	○	○	○	○	○	●
Better Car and Equipment Washing	◑	●	◑	○	○	◑	◑
Better Sidewalk and Driveway Cleaning	●	◑	◑	○	◑	◑	◔
Better Sidewalk and Driveway Deicing	◑	◔	◔	○	○	○	◑
Proper Pool Discharge	○	○	○	○	○	○	●
Septic Tank Maintenance	◔	●	○	●	○	○	◔
Exposed Soil Repair	●	◑	◔	◔	○	○	○
Native Landscaping	●	●	◔	◔	◔	○	○
Healthy Lawns	●	◑	◔	◔	○	○	○

Legend

○ = Uncontrolled	◑ = Moderately Controlled
◔ = Slightly Controlled	● = Significantly Controlled

Source: modified from the Center for Watershed Protection

Table 8.2 Residential Pollution Prevention Methods

Practice		Method
	Fertilizer and Pesticide Management[1]	Reduce or eliminate the need for fertilizer and pesticides by practicing natural lawn care, planting native vegetation, and limiting chemical use; follow Minnesota Statutes Chapter 18C and federal regulatory requirements on fertilizer and pesticide storage and application if used.
	Litter and Animal Waste Control[1]	Properly dispose of pet waste and litter in a timely manner and according to local ordinance requirements.
	Yard Waste Management[1]	Prevent yard waste from entering storm sewer systems and water bodies by either composting or using curbside pickup services and avoiding accumulation of yard waste on impervious surfaces; keep grass clippings and leaves out of the street.
	Household Hazardous Waste (HHW) Control[1]	Ensure that hazardous waste, including paints, stains, solvents, cleaning products, used motor oil, antifreeze, and pesticides, are disposed of properly by participating in a County household hazardous waste collection program; properly store hazardous waste items.
	Alternative Product Use	Use less harmful products including alternative cleaning solutions, pesticides, fertilizers, automotive and paint products to reduce the amount of toxic substances released into sewer systems.
	Better Car and Equipment Washing[1]	Wash cars less often and on grassy areas using phosphorus-free detergents and non-toxic cleaning products or use commercial car washes to prevent dirty wash water from flowing to storm sewer systems and water bodies.
	Better Sidewalk and Driveway Cleaning[1]	Sweep sidewalks and driveways and dispose of sweepings in the trash instead of using hoses or leaf blowers to clean surfaces.
	Better Sidewalk and Driveway Deicing[1]	Reduce or eliminate the need for deicing products by manually clearing sidewalks and driveways prior to deicer use; use environmentally-friendly deicing products when possible, apply sparingly and store properly if used.
	Proper Pool Discharge[1]	Check local ordinances for pool water discharge requirements; pool water should be discharged to sanitary sewer systems or held for a week or more without addition of chlorine prior to spreading over pervious areas to prevent stormwater contamination.
	Exposed Soil Repair[1]	Use native vegetation or grass to cover and stabilize exposed soil on lawns to prevent sediment wash off.
	Native Landscaping	Reduce turf areas by planting native species to reduce and filter pollutant-laden runoff and prevent the spread of invasive, non-native plant species into the storm sewer system.
	Healthy Lawns	Maintain thick grass planted in organic-rich soil to a height of at least 3 inches to prevent soil erosion, filter stormwater contaminants, and absorb airborne pollutants; limit or eliminate chemical use and water and repair lawn as needed.

MUNICIPAL PRACTICES

Salt delivery to a Washington County Salt Shed

Definition:
Municipal pollution prevention practices are public operation and maintenance activities and educational efforts implemented by municipal staff that prevent or reduce the contamination of stormwater.

KEY CONSIDERATIONS

Description:
Municipal pollution prevention practices prevent or reduce stormwater contamination from public sources such as streets, parking areas, maintenance vehicles, storm and sanitary sewers, dumpsters, swimming pools and other potential stormwater hotspots. These practices improve subwatershed water quality by minimizing the introduction of pollutants including sediment, nutrients, metals, bacteria, trash, oil, and toxins. Each of these practices is highly suitable and effective in cold climates. Table 8.3 indicates the pollutants controlled by various municipal pollution prevention practices while Table 8.4 describes some of the methods used for each of these practices. See Chapter 6 for further discussion of potential stormwater hotspots. See Photo Credits and References for further information.

Table 8.3 Municipal Practices Pollutant Controls

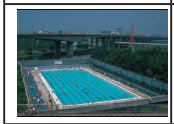
Practice	Stormwater Pollutants Controlled						
	Sediment	Nutrients	Metals	Bacteria	Trash	Oil	Toxins
Temp. Construction Sediment Control	●	◑	◔	○	◔	○	○
Wind Erosion Control	●	◑	◔	○	◔	○	○
Streambank Stabilization	●	◑	○	○	○	○	○
Material Storage Control	●	◑	◑	○	○	●	●
Dumpster and Landfill Management	◔	◑	◑	●	●	◑	●
Proper Pool Discharge	○	○	○	○	○	○	●
Better Turf Management	◑	●	○	○	○	○	●
Better Street and Parking Lot Cleaning	●	◑	◑	○	◑	◑	◔
Better Street and Parking Lot Deicing	◑	◔	◔	○	○	○	●
Proper Vehicle Management	●	●	●	○	◑	●	●
Storm Sewer System Maintenance	●	◑	◔	○	◑	○	○
Sanitary Sewer System Maintenance	◔	●	○	●	○	○	◔
Litter and Animal Waste Control	○	●	○	●	●	○	○
Public Education	◑	◑	◑	◑	◑	◑	◑
Staff and Employee Education	◑	◑	◑	◑	◑	◑	◑

Legend

○ = Uncontrolled	◑ = Moderately Controlled
◔ = Slightly Controlled	● = Significantly Controlled

Source: Modified from the Center for Watershed Protection

Table 8.4 Municipal Pollution Prevention Methods

Practice		Method
	Temporary Construction Sediment Control	Implement and encourage practices to retain sediment within construction project area; see Temporary Construction Erosion and Sediment Control Factsheets for additional information.
	Wind Erosion Control	Institute a local program for wetting of open construction surfaces and other sources for windblown pollutants.
	Streambank Stabilization	Repair erosion occurring on a streambank of lakeshore in a timely manner; inspect bank areas for ice damage in the spring.
	Material Storage Control	Reduce or eliminate spill and leakage loss by properly inspecting, containing, and storing hazardous materials and having a cleanup plan that can be quickly and efficiently implemented.
	Dumpster and Landfill Management	Ensure that contaminated material is contained to prevent solid and/or liquid waste from being washed into storm sewer systems or water bodies.
	Proper Pool Discharge	Discharge pool water to sanitary sewer systems or hold for a week or more without the addition of chlorine prior to spreading over pervious areas instead of draining water directly to storm sewer systems. Follow local ordinances.
	Better Turf Management	Ensure that mowing, fertilization, pesticide application, and irrigation are completed in ways that will prevent or reduce grass clippings, sediment, and chemicals from entering storm sewer systems; use native vegetation where possible.
	Better Street and Parking Lot Cleaning	Maintain streets and parking lots frequently and especially in the spring by sweeping, picking up litter, and repairing deterioration; pressure wash pavement only as needed and avoid using cleaning agents.
	Better Street and Parking Lot Deicing	Properly store and conservatively apply salt, sand, or other deicing substances in order to prevent excessive and/or unnecessary contamination; implement anti-icing and prewet salt techniques for increased deicing efficiency.
	Proper Vehicle Management	Ensure that vehicles are fueled, maintained, washed and stored in a manner that prevents the release of harmful fluids, including oil, antifreeze, gasoline, battery acid, hydraulic and transmission fluids, and cleaning solutions.
	Storm Sewer System Maintenance	Regularly clean debris from storm sewer inlets, remove sediment from catch basin sumps, and remove any illicit connections to storm sewer systems.
	Litter and Animal Waste Control	Mandate litter and pet waste cleanup within the community and control waste-generating wildlife, such as geese; provide waste containers for litter and pet waste in public areas.
	Public Education	Label storm drains to indicate that no dumping is allowed and institute pollution prevention programs to educate and implement needed community practices.
	Staff, Employee, and Volunteer Education	Provide internal training for staff and provide direction to hired employees or volunteers regarding pollution prevention techniques to be used during work activities.

INDUSTRIAL & COMMERCIAL PRACTICES

Definition:
Industrial and commercial pollution prevention practices are private operation and maintenance activities implemented by owners or individuals responsible for industrial and commercial sites that prevent or reduce the contamination of stormwater.

KEY CONSIDERATIONS

Description:
Industrial and commercial pollution prevention practices prevent or reduce stormwater contamination from concentrated impervious surfaces and potential stormwater hotspots such as streets, parking areas, vehicles, smokestacks, and dumpsters. These practices improve subwatershed water quality by minimizing the introduction of pollutants including sediment, nutrients, metals, bacteria, trash, oil, and toxins. Table 8.5 indicates the pollutants controlled by various industrial and commercial pollution prevention practices while Table 8.6 describes some of the methods used for each of these practices. See Chapter 6 for further discussion of potential stormwater hotspots. See Photo Credits and References for further information.

Table 8.5 Industrial & Commercial Practices Pollutant Controls

Practice	Stormwater Pollutants Controlled						
	Sediment	Nutrients	Metals	Bacteria	Trash	Oil	Toxins
Temp. Construction Sediment Control	●	◑	◔	○	◔	○	○
Wind Erosion Control	●	◑	◔	○	◔	○	○
Emission Regulation	◔	○	●	○	●	○	●
Material Storage Control	●	◑	◑	○	○	●	●
Dumpster and Landfill Management	◔	◑	◑	●	●	◑	●
Better Turf Management	◑	●	○	○	○	○	●
Better Parking Lot Cleaning	●	◑	◑	○	◑	◑	◔
Better Impervious Surface Deicing	◑	◔	◔	○	○	○	●
Proper Vehicle Management	●	●	●	○	◑	●	●
Storm Sewer System Maintenance	●	◑	◔	○	◑	○	○
Sanitary Sewer System Maintenance	◔	●	○	●	○	○	◔

Legend

○ = Uncontrolled ◑ = Moderately Controlled

◔ = Slightly Controlled ● = Significantly Controlled

Source: Modified from the Center for Watershed Protection

Table 8.6 Industrial & Commercial Pollution Prevention Methods

	Practice	Method
	Temporary Construction Sediment Control	Follow local, state, and federal regulatory requirements for control of erosion during construction activities.
	Wind Erosion Control	Institute a local program for wetting of open construction surfaces and other sources for windblown pollutants.
	Emission Regulation [1]	Follow local, state, and federal regulatory requirements for control of air emissions.
	Material Storage Control [1]	Reduce or eliminate spill and leakage loss by properly inspecting, containing, and storing hazardous materials and having a cleanup plan that can be quickly and efficiently implemented. Follow NPDES Industrial Permit requirements if permit authority applies.
	Dumpster and Landfill Management	Ensure that contaminated material is contained to prevent solid and/or liquid waste from being washed into storm sewer systems or water bodies.
	Better Turf Management [1]	Ensure that mowing, fertilization, pesticide application, and irrigation are completed in ways that will prevent or reduce grass clippings, sediment, and chemicals from entering storm sewer systems; use native vegetation where possible.
	Better Parking Lot Cleaning [1]	Maintain parking lots frequently and especially in the spring and fall by sweeping, picking up litter, and repairing deterioration; pressure wash pavement only as needed and minimize the use of cleaning agents.
	Better Impervious Surface Deicing [1]	Reduce or eliminate the need for deicing products by manually clearing sidewalks, driveways, and parking lots prior to deicer use; use environmentally-friendly deicing products when possible, apply sparingly and store properly if used.
	Proper Vehicle Management [1]	Ensure that vehicles are fueled, maintained, washed and stored in a manner that prevents the release of harmful fluids, including oil, antifreeze, gasoline, battery acid, hydraulic and transmission fluids, and cleaning solutions.
	Storm Sewer System Maintenance	Regularly clean debris from storm sewer inlets, remove sediment from catch basin sumps, and remove any illicit connections to storm sewer systems.
	Sanitary Sewer System Maintenance [2]	Regularly inspect and flush sanitary pipes to ensure that there are no leaks in the system and that the system is functioning properly.

Note: See page 7 for photo credits

Photo Credits

1. Courtesy of the Center for Watershed Protection
2. Courtesy of the Town of Amherst, New York
3. Courtesy of the United States Geological Survey

All other photos from EOR

VII. References & Photo Credits

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Math & Science Academy - infiltration trench
Woodbury, MN

KEY CONSIDERATIONS

Few watershed management practices simultaneously reduce pollutant loads, conserve natural areas, save money, and increase property values. Indeed, if such "wonder practices" were ever developed, they would certainly spread quickly across the nation. As it turns out, these practices have existed for years. Collectively called "better site design," the techniques employ a variety of methods to reduce total paved area, distribute and diffuse stormwater, and conserve natural habitats.

Better site design is a fundamentally different approach to residential and commercial development. It seeks to accomplish three goals at every development site: to reduce the amount of impervious cover, to increase natural lands set aside for conservation, and to use pervious areas for more effective stormwater treatment. To meet these goals, designers must scrutinize every aspect of a site plan— its streets, parking spaces, setbacks, lot sizes, driveways, and sidewalks— to determine if any of these elements can be reduced in scale. At the same time, creative grading and drainage techniques reduce stormwater runoff and encourage more infiltration.

Fields of St. Croix - stormwater finishing pond
Lake Elmo, MN

BETTER SITE DESIGN

Use the following outline as a guide to better site design (early on and throughout the design process) for development, redevelopment and retrofits. The first goal should be to minimize stormwater runoff. Mitigating any generated stormwater should be the second goal.

MINIMIZE STORMWATER RUNOFF

USE HYDROLOGY AS THE INTEGRATING FRAMEWORK

- Reproduce predevelopment hydrology
- Create a multifunctional landscape, which incorporates stormwater features into the landscape
- Use surface water elements as the focal point in civic spaces

PRESERVE AND EMULATE NATURAL DRAINAGE

- Utilize existing flow paths
- Fit development to the terrain
- Restore the drainage and/ or biological capacity of damaged or lost soils through mechanical improvements or soil amendments

SITE FINGERPRINTING

- Incorporate smaller lot sizes to minimize total impervious
- Confine construction and development to least critical / sensitive areas
- Preserve open space / natural areas
- Reduce limits of clearing and grading
- Stage construction (limit area exposure of the site at any one time)
- Minimize soil compaction

IMPERVIOUS SURFACES

- Reduce
- Minimize
- Disconnect

MITIGATE STORMWATER RUNOFF

THINK MICROMANAGEMENT

- Control runoff at the source
- Minimize runoff by maximizing infiltration, evapotranspiration, and filtration
- Employ natural processes for water quality improvement

STORMWATER TREATMENT TRAIN

- Utilize simplistic, non-structural methods
- Use redundant runoff treatment systems
- Highly suitable for cold climates

RESIDENTIAL STREETS & PARKING LOTS

KEY CONSIDERATIONS

Model development principles provide design guidance for economically viable, yet environmentally sensitive development. The key objective is to provide planners, developers, and local officials with benchmarks to investigate where existing ordinances may be modified to reduce impervious cover, conserve natural areas, and prevent stormwater pollution. The City of Inver Grove Heights identified areas where existing codes and standards could be changed to better protect streams, lakes and wetlands in the Northwest Area and incorporated those changes into the PUD. These principles are also highly suitable and effective in cold climates.

Each principle is presented as a simplified design objective. Actual techniques for achieving the principle should be based on local conditions. Please consult Chapter 4 for more detailed information on better site design.

EXAMPLES

Fields of St. Croix - Lake Elmo, MN

This residential conservation development uses minimum road widths and landscaped areas to reduce the amount of impervious surfaces and add to the rural character of the neighborhood. Vegetated channels and bioretention areas are used in the right-of-way to treat stormwater runoff.

H.B. Fuller - Vadnais Heights, MN

This parking lot incorporates bioretention strategies to treat stormwater runoff. The landscaped depressions provide stormwater treatment, snow storage, and improved parking lot aesthetics and climate. Low maintenance sedges are used in place of traditional turf grass to lower maintenance costs and pollution.

BETTER SITE DESIGN

Use the following checklist as a tool to better site design (early on and throughout the design process) for street and parking lot development, redevelopment and retrofits. Place a check in the appropriate boxes if you think that this approach will work for your site.

RESIDENTIAL STREETS AND PARKING LOTS CHECKLIST

✓	Design residential streets for the minimum required pavement width needed to support travel lanes, on-street parking, and emergency, maintenance, and service vehicle access. For public streets install 28 foot paved width streets with a sidewalk/trail on one side (24 foot for private streets)
✓	Minimize the number of residential street cul-de-sacs and incorporate landscaped areas to reduce impervious cover. The radius of cul-de-sacs should be 35 feet. Consider alternative turnarounds.
	Wherever possible, residential street right-of-way widths should reflect the minimum required to accommodate the travel-way, the sidewalk, and vegetated open channels. Utilities and storm drains should be located outside of the BMPs section of the right-of-way wherever feasible.
	Reduce the total length of residential streets by examining alternative street layouts to determine the best option for increasing the number of homes per unit length.
	Where density, topography, soils, and slope allow, vegetated open channels should be used in the street right-of-way to convey and treat stormwater runoff.
	Enforce the required parking ratio governing a particular land use or activity as both a maximum and a minimum, in order to curb excess parking space construction. Existing parking ratios should be reviewed for conformance, taking into account local and national experience to determine if lower ratios are warranted and feasible.
	Reduce the overall imperviousness associated with parking lots by providing compact car spaces, minimizing stall dimensions, incorporating efficient parking lanes, making use of vegetated parking islands, and using pervious materials in spillover parking areas where possible.
	Provide stormwater treatment, wherever possible, for parking lot runoff using bioretention areas, filter strips, and/or other practices that can be integrated into required landscaping areas and traffic islands.

KEY CONSIDERATIONS

Model development principles provide design guidance for economically viable, yet environmentally sensitive development. The City of Inver Grove Heights has identified areas where existing codes and standards could be changed to better protect streams, lakes and wetlands in the Northwest Area and incorporated those changes into the PUD. These principles are also highly suitable and effective in cold climates.

Each principle is presented as a simplified design objective. Actual techniques for achieving the principle should be based on local conditions. Please consult Chapter 4 for more detailed information on better site design.

EXAMPLES

Jackson Meadow - Marine on St. Croix, MN

Flexible design standards promote open space design development. Design standards encourage reductions of overall imperviousness, smaller lot sizes, preservation of natural areas, community open space, watershed protection, and unique neighborhood identity.

Lilydale - Inver Grove Heights, MN

Shared driveways in a development can significantly reduce the amount of overall imperviousness.

BETTER SITE DESIGN

Use the following checklist as a tool to better site design (early on and throughout the design process) for street and parking lot development, redevelopment and retrofits. Place a check in the appropriate boxes if you think that this approach will work for your site.

LOT DEVELOPMENT CHECKLIST

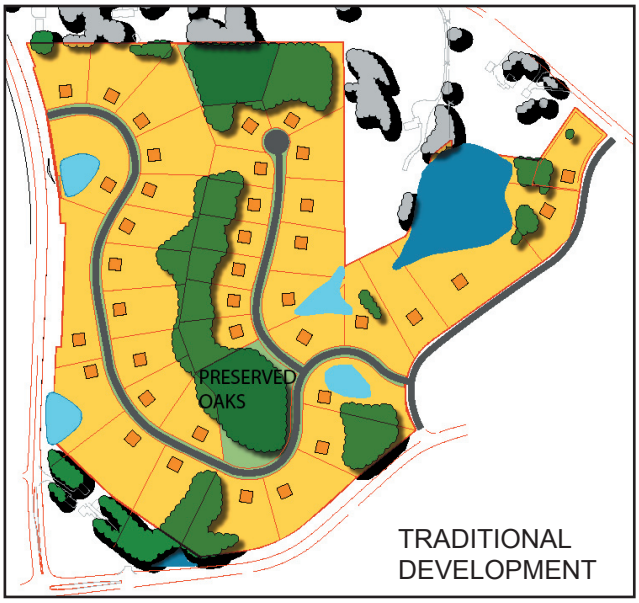
✓	Reduce overall lot imperviousness by installing alternative driveway surfaces, shorter or narrower (<20 feet) driveways, and shared driveways that access two or more homes.
	Clearly specify how community open space will be managed, and designate a sustainable legal entity responsible for managing both natural and recreational open space.
	Direct rooftop runoff to pervious areas such as yards, open channels, or vegetated areas and avoid routing rooftop runoff to the roadway and the stormwater conveyance system.
	Restore the drainage and/ or biological capacity of damaged or lost soils through mechanical improvements or soil amendments.
	Consider joint parking arrangements or other methods (underground parking, tuckunder parking, etc.) for reducing the size of parking lots.
	Where possible incorporate pervious surfaces for parking surfaces, turn arounds, patios, sidewalks and/or driveways.
	Consider open space design development incorporating smaller lot sizes to minimize total impervious area, reduce total construction costs, conserve natural areas, provide community recreational space, and promote watershed protection.

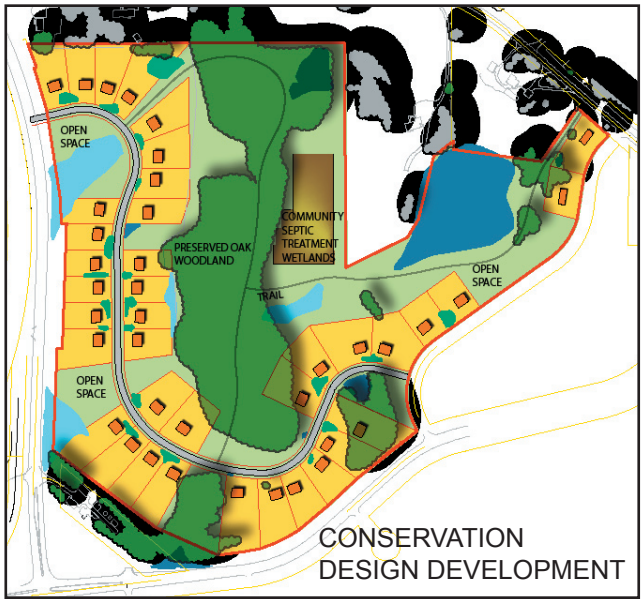
CONSERVATION OF NATURAL AREAS

KEY CONSIDERATIONS

Model development principles provide design guidance for economically viable, yet environmentally sensitive development. The City of Inver Grove Heights has identified areas where existing codes and standards could be changed to better protect streams, lakes and wetlands in the Northwest Area and incorporated those changes into the PUD. These principles are also highly suitable and effective in cold climates.

Each principle is presented as a simplified design objective. Actual techniques for achieving the principle should be based on local conditions. Please consult Chapter 4 for more detailed information on better site design.





COMPARISON

Traditional Residential Developments vs. Conservation Design Developments

Flexible design standards can allow for the conservation of a site's natural areas and ecological function. Conservation design developments advocate preserving a site's most distinguishing natural features and integrating them into the community of the new development. Open space should be consolidated to have the greatest recreational, aesthetic, and environmental benefit.

Smaller lot sizes allow the same densities as a traditional development, with more open space dedicated as a community amenity. Flexible lot design allows less roads and stormwater infrastructure to be built, reducing imperviousness and infrastructure costs.

BETTER SITE DESIGN

Use the following checklist as a tool to better site design (early on and throughout the design process) for development, redevelopment and retrofits. Place a check in the appropriate boxes if you think this approach will work in your site.

CONSERVATION OF NATURAL AREAS CHECKLIST

✓	Preserve at least 20% of the net developable areas within the PUD as additional natural area/open space. This may include greenways as shown in the Inver Grove Heights Natural Resources Inventory and Management Plan.
✓	Open space design or cluster development is promoted as a means of conserving natural areas by allowing an increased mixture of housing types for each zoning district.
✓	Wetland management standards assign slope-dependent buffer width to each wetland management classification
	Conserve trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native plants. Wherever practical, manage community open space, street rights-of-way, parking lot islands, and other landscaped areas.
	Prevent the discharge of unmanaged stormwater from new stormwater outfalls into wetlands, sole-source aquifers, or ecologically sensitive areas.
	Preserve or restore riparian wetland buffers with native vegetation. Maintain the buffer system through the plan review delineation, construction, and post-development stages.
	Limit clearing and grading of forests and native vegetation at a site to the minimum area needed to build lots, allow access, and provide fire protection. Manage a fixed portion of any community open space as protected green space in a consolidated manner.

Site without temporary sediment control

Site with temporary sediment control

Definition:

Temporary construction erosion and sediment control is the practice of preventing or reducing the movement of sediment from a site during construction through the implementation of man-made structures, land management techniques, or natural processes. Note that this Fact Sheet does not contain detail on the use of specific BMPs. Because there are many good resources on erosion and sediment control, this Fact Sheet merely discusses their use and refers the reader to other useful resources for detail.

DESCRIPTION

Temporary construction erosion and sediment control limits the amount of sediment that is carried into lakes, wetlands, and infiltration facilities by storm water runoff. Sediment can clog the bottom of infiltration practices and also carries nutrients and pollutants that degrade water resources and harm aquatic wildlife. Proper planning of construction site activities greatly reduces the impact of soil disturbance activities on nearby resources and diminishes the need for costly restorations. A construction plan that limits sediment disturbance in potential problem areas and uses effective temporary sediment control practices will lessen negative impacts to local water resources and infiltration practices.

To establish a construction plan that will minimize sediment movement, designers will need information on existing site conditions and neighboring resources that require special consideration including water bodies, natural areas, bluffs and other highly erodible or sensitive areas. Construction activities should be designed in a manner that minimizes overall soil disturbance and phases areas of disturbance such that the amount of land disturbed at any one time is reduced. This type of planning will limit the need for larger structural sediment control solutions. Additionally, the designer should determine which local, state, and federal agencies require permits for the type of work planned. The site plan will need to account for the requirements of all agencies issuing permits.

In a closed basin system like the Northwest Area, infiltration is a major component of the stormwater management strategy. Temporary construction erosion and sediment control is critical for protecting these sensitive infiltration areas from clogging and ensuring that they function properly. Inver Grove Heights city code requires that a site construction plan, including details of the temporary construction erosion and sediment control practices, be submitted with the Storm Water Management Plan.

Photo: MPCA

The practices included in the site construction plan and SWPPP (if one is required for the project by state law) will need to control runoff, stabilize slopes and exposed soils, and limit the movement of soils into infiltration practices, receiving waters, and natural areas. A key factor in accomplishing these goals is the sequencing of construction activities such that the minimum possible area is disturbed at any one time. Initial site work should include establishing protective buffer zones adjacent to onsite resources, including infiltration areas, that require protection and setting up perimeter sediment controls. During the course of construction, a variety of erosion prevention and sediment control practices may be necessary in order to stabilize slopes and drainageways, protect inlets to the storm water conveyance system, protect infiltration practices, limit gully formation, and capture sediment. Table 8.7 summarizes some of the most common temporary erosion and sediment control practices, the on-site areas to use the practices, and the method of use for each of the practices. Table 8.8 indicates requirements and the temporary sediment control practices that can be used to fulfill these requirements. Temporary seeding is not erosion protection or sediment control until vegetation is established or until the area is protected with an erosion control blanket. Projects that are actively under construction in winter/ frozen months should include additional inspection and clean-up activities. Temporary sediment basins should be sized to include extra storage for snowmelt, as discussed in Chapter 6. Temporary sediment basins should not be located in areas that will be used for infiltration practices once construction is complete.

A final key element to ensure effectiveness of the erosion and sediment control plan is the implementation of an inspection and maintenance program. Frequent inspection and maintenance activities ensure that the installed temporary sediment control practices are operating effectively throughout the course of the project.

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Table 8.7 Temporary Sediment Control Practices

Temporary Sediment Control Practice		Erosion Protection	Sediment Control	Areas to Use				Method
				Perimeter	Slopes	Drainage-ways	Other	
	Vegetated Buffers Photo: MPCA	X		X	X	X	Around Trees, Water Bodies, Natural Areas	Vegetated buffers are areas designated to remain undisturbed in order to protect lakes, wetlands, infiltration zones or natural areas. Buffers should be marked and maintained around all resources requiring protection.
	Silt Fence		X	X	X	X	Drainage System Inlets, Infiltration Areas	Silt fence filters sediment from runoff by allowing water to pass through a geotextile fabric or by creating a pool to allow sediment to drop out of the water column. Silt fence is installed primarily at downslope boundaries of the work area but can also be used for inlet protection, identification of infiltration areas and around the perimeter of stockpiles.
	Fiber Log		X	X	X	X	Drainage System Inlets	Fiber logs include straw, wood, or coconut fiber logs, compost logs, and rock logs that slow water and filter sediment. Fiber logs are used for inlet protection, ditch checks, and as perimeter control where silt fence is infeasible.
	Rock Construction Entrance		X	X				A rock construction entrance is a bed of rocks that helps to remove sediment from vehicle tires. Rock construction entrances should be placed at all site access points. The use of 1 1/2 inch - 3 inch clear aggregate is recommended. Periodic cleaning or replacement is recommended.
	Grade Breaks		X		X			Grade breaks are changes in slope that break up concentrated flow, preventing the formation of gullies. Grade breaks should be incorporated into long slopes.
	Temporary Seeding	X	X		X	X		Temporary seeding allows plants to stabilize the soil through vegetation and root growth. A large variety of plants are available for temporary seeding of different conditions; the most common are rye grass, winter wheat, and oats.
	Erosion Control Blanket	X	X		X	X		Erosion control blanket is a mat made of netting layered with straw, wood, coconut or man-made fibers that prevents erosion by sheltering the soil from rainfall and runoff while holding moisture for establishing plants. Blankets are installed in channels or on slopes where mulch would not be adequate.

Table 8.7 Temporary Sediment Control Practices

Temporary Sediment Control Practice		Erosion Protection	Sediment Control	Areas to Use				Method
				Perimeter	Slopes	Drainageways	Other	
	Mulch	X			X			Mulch is wood fibers, compost, wood chips, straw, or hay that is applied as a cover to disturbed soil. Mulch reduces erosion by absorbing energy from rainfall and runoff and provides protection and moisture for the establishment of vegetation, when properly disc anchored or spread.
	Hydraulic Mulch	X			X			Hydraulic mulches for erosion control are typically comprised of wood fibers and are applied by hydroseeding equipment. Hydraulic mulches are typically used in areas with steeper slopes or where equipment access would be difficult.
	Temporary Pipe Downdrains	X			X			A temporary pipe downdrain conveys runoff down slopes in a pipe so that runoff will not cause erosion. Pipe downdrains are installed where concentrated flow would drain onto a disturbed slope.
	Flotation Silt Curtain		X				Lakes, Wetlands, Streams	Flotation silt curtain is fabric fence installed in water bodies to contain sediment near the banks of the work area. Must be used in conjunction with other sediment control techniques
	Rock or Compost Bags		X		X	X	Drainage System Inlets	Rock and compost bags are filled bags that are used to filter water, control ditch grade, or to provide inlet protection.
	Rock Check Dam		X			X		Rock check dams are rocks piled across a ditch to slow flows and capture sediment. Rock checks are installed perpendicular to flow and should be wide enough to ensure that flow remains in the center.
	Riprap	X				X	Drainage System Outlets	Riprap is appropriately sized rocks that reduce the energy of fast moving flows. Riprap is used along channels and at outfalls.
	Temporary Sedimentation Basin		X				Throughout Site	Temporary sedimentation basins are depressions that capture runoff to slow the flow of water and allow sediment to settle out.
	Filter Bag Photo: Dandy Corp.		X				Drainage System Inlets	Filter bags are mesh bags that capture sediment but allow water to pass through. Filter bags are installed in storm drain inlets.

Table 8.8 NPDES and Inver Grove Heights Requirements and Associated Erosion Protection and Sediment Control Practices

NPDES General Construction Storm water Permit Requirement * *specific requirements may vary as specified in General Permit Appendix A	Temporary Erosion Protection and/or Sediment Control Practice															
	Vegetated Buffers	Silt Fence	Fiber Log	Rock Construction Entrance	Grade Breaks	Temporary Seeding	Erosion Control Blanket	Mulch	Hydraulic Mulch	Temporary Pipe Downdrains	Flotation Silt Curtain	Rockbags/Sandbags/ Compostbags	Rock Check Dam	Riprap	Sedimentation Basin	Filter Bag
Delineate areas of no disturbance before beginning site work.	X															
Sediment control must be established on all down gradient perimeters prior to commencement of land disturbing activities.		X	X								X					
Vehicle tracking of sediment must be minimized.				X												
All storm drain inlets must be protected.		X	X									X				X
Install energy dissipation measures at pipe outlets within 24 hours of connecting to a surface water.														X		
Drainage ditches within 200 feet of a surface water or the property edge must be stabilized within 24 hours of connection to a surface water.			X			X	X	X*	X*				X	X		
No unbroken slope of length greater than 75 feet for slopes of 3:1 or steeper.																
Slopes within 200 feet of a surface water must have temporary protection or permanent cover within the following time frame based on slope: **Slope** — **Time** Steeper than 3:1 — 7 days 10:1 to 3:1 — 14 days Flatter than 10:1 — 21 days			X		X	X	X	X	X	X						
Install temporary basin where 10 acres or more drains to a common location.															X	
Infiltration / open space areas shall be staked off during construction to restrict heavy equipment traffic from compacting native soils and/or prevent these areas from becoming staging areas																

Table 8.8 NPDES and Inver Grove Heights Requirements and Associated Erosion Protection and Sediment Control Practices																
NPDES General Construction Storm water Permit Requirement *	Temporary Erosion Protection and/or Sediment Control Practice															
*specific requirements may vary as specified in General Permit Appendix A	Vegetated Buffers	Silt Fence	Fiber Log	Rock Construction Entrance	Grade Breaks	Temporary Seeding	Erosion Control Blanket	Mulch	Hydraulic Mulch	Temporary Pipe Downdrains	Flotation Silt Curtain	Rockbags/Sandbags/ Compostbags	Rock Check Dam	Riprap	Sedimentation Basin	Filter Bag
If the stormwater BMP is being designed to serve as a temporary sediment basin, grade the BMP to within three (3) feet of final grade to protect the underlying material from clogging. Once construction in the contributing drainage area has been completed and the site is stabilized, excavate the infiltration practice to final grade and complete construction of the BMP																

Source: Modified from the Minnesota Stormwater Manual

VI. Guidance Documents

Guidance documents have been developed for those best management practices that provide a reduction in the volume of stormwater runoff leaving the site. Guidance documents contain more in depth design information and considerations than could be contained in a fact sheet alone. The order these guidance documents are presented reflects the order they would be used if applying a treatment train approach to stormwater management. Guidance documents have been developed for the following BMPs.

- Green Roofs
- Rainwater Harvesting
- Pervious Surfaces
- Filtration
- Bioretention
- Infiltration
- Stormwater Ponds
- Stormwater Wetlands
- Soil Amendments

GREEN ROOFS

Courtesy of The Green Institute - Minneapolis, MN

Definition:
Green roofs consist of a series of layers that create an environment suitable for plant growth without damaging the underlying roof system. Green roofs create green space for public benefit, energy efficiency, and stormwater retention/ detention.

KEY CONSIDERATIONS

Design Criteria:

- Structural load capacity, how much weight the roof can hold, is a major factor in determining whether the green roof is "extensive" or "intensive" (see next page).
- Vegetation selection is based on numerous factors including, growth medium depth, microclimate, irrigation availability and maintenance.
- A leak detection system is recommended to quickly detect and locate leaks.
- Modular products can increase installation and repair efficiency.

Benefits:

- Reduce, delay, and cool stormwater runoff.
- Insulate buildings and lower energy consumption and costs.
- Provide habitat for birds and insects.
- Increase longevity of traditional roofing systems by protecting from ultraviolet rays.
- Reduce carbon dioxide levels and heat island effect.

Limitations:

- Cost is higher than traditional roofing systems – can be significant for retrofits.
- Leaks can cause significant damage and can be hard to locate and repair without an electronic leak detection system.
- Conditions can be harsh for vegetation establishment.
- Maintenance needs can be higher than traditional roofing system.

MANAGEMENT SUITABILITY

X	Volume Control
X	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
X	Wetland Bounce

MECHANISMS

X	Infiltration *with appropriate soil & conditions
X	Screening/ Filtration
X	Temperature Control
	Settling
X	Evaporation
X*	Transpiration *if vegetated
X	Soil Adsorption
X	Biological/ Micro. Uptake

POLLUTION REMOVAL

NA	Total Suspended Solids
NA	Nutrients - Total Phosphorus/ Total Nitrogen
NA	Metals - Cadmium, Copper, Lead, and Zinc
NA	Pathogens - Coliform, Streptococci, E. Coli
NA	Toxins - Chloride, Hydrocarbons, Pesticides

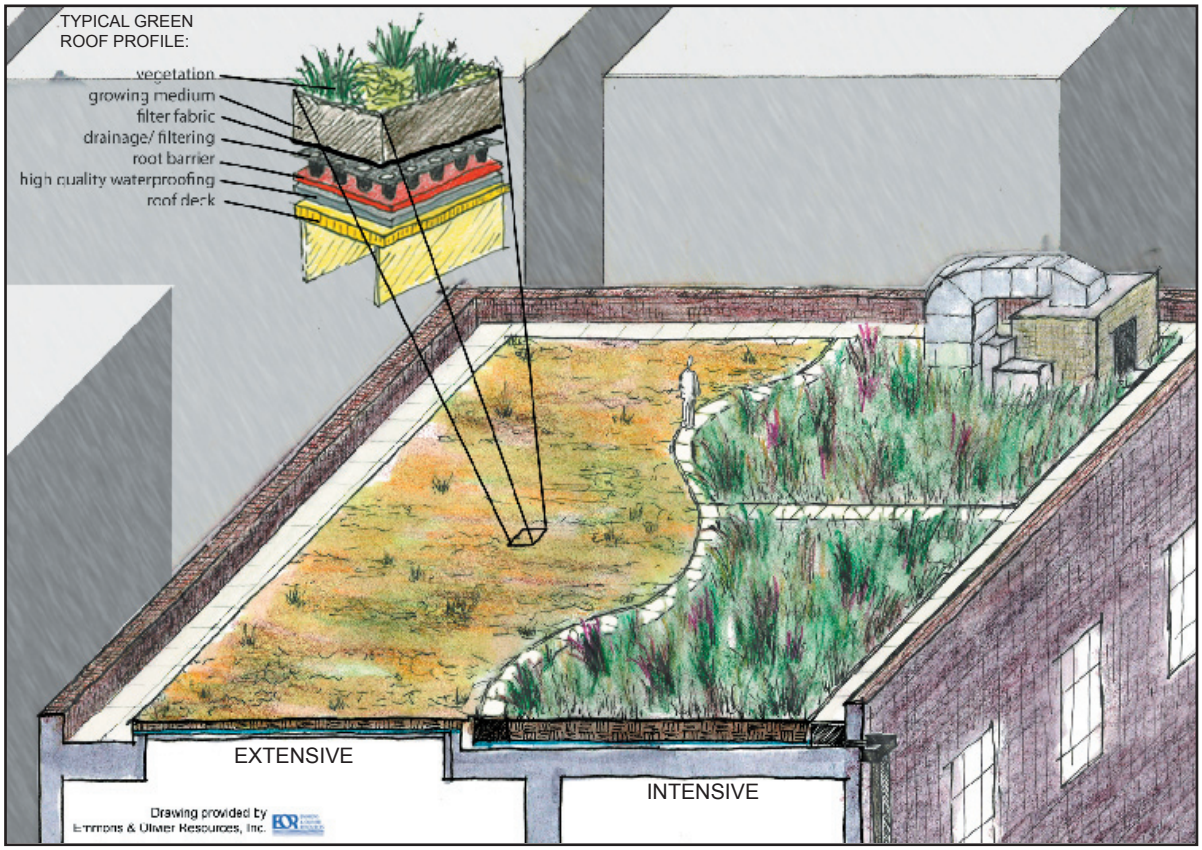
Note: Pollution removal percentages apply to volume of runoff treated, and not to volume by-passed

SITE FACTORS

Rooftop	Drainage Area
30%	Max. Slope *additional slippage control used for slopes >30%
NA	Min. Depth to Bedrock
NA	Min. Depth to Water Table
NA	SCS Soil Type *can be used in C&D soil types with modifications (e.g. underdrains)
Good	Freeze/ Thaw Suitability
NA	Potential Hotspot Runoff *requires impermeable liner

Description:
There are two systems of green roofs, extensive and intensive, composed of the same system of layers. Extensive systems are lighter, typically have 4 inches or less of growing medium, use drought tolerant vegetation, and can structurally support limited uses (such as maintenance personnel). Intensive systems are heavier, have a greater soil depth, can support a wider range of plants, and can support increased pedestrian traffic.

Rainfall is initially intercepted by vegetation, held on foliage, or soaked up by plant roots. Any remaining runoff filters through the growing medium and is drained away from the roof's surface by the drainage layer. Some drainage systems use small depressions to store excess water for uptake during drier conditions (RCWD 2005), while others provide an overflow for larger rainfall events.



Courtesy of Rice Creek Watershed District

A. Suitability

General

Green roofs consist of a series of layers that create an environment suitable for plant growth without damaging the underlying roof system. Green roofs create green space for public benefit, energy efficiency, and stormwater retention/ detention. Design variants include; extensive use and intensive use green roofs. Rainfall is initially intercepted by vegetation, held on foliage, or soaked up by plant roots. Any remaining runoff filters through the growing medium and is drained away from the roof's surface by the drainage layer. Some drainage systems use small depressions to store excess water for uptake during drier conditions (RCWD 2005), while others provide an overflow for larger rainfall events.

Function Within Stormwater Treatment Train

Green roofs are the first step in the treatment train. They can be designed to provide stormwater reduction, detention and cooling. The practice may be applied as part of a stormwater management system to achieve the following objectives:

- reduce stormwater pollutants (through reduced total runoff)
- decrease runoff peak flow rates
- decrease the volume of stormwater runoff
- reduce thermal impacts of runoff.

Inver Grove Heights Permit Applicability

One of the goals of this manual is to facilitate an understanding of and compliance with the City of Inver Grove Heights' volume control standard. This standard must be met on all new and re-development projects taking place in the northwest area.

Green roofs should be designed for volume control. Storage should be provided so that rainfall is collected and stored before evaporating or transpiring back to the atmosphere. Volume reduction may be applied to the 5-year 24-hour standard for any storage provided below the roof overflow elevation. Additionally, volume credit may be allowed above the roof overflow but the amount of volume credit will be based on substrate properties and will need to be approved by the city engineer.

The following terms are thus used in the text to distinguish various levels of green roof design guidance:

REQUIRED:	Indicates design standards stipulated by the IGH PUD.
HIGHLY RECOMMENDED:	Indicates design guidance that is extremely beneficial or necessary for proper functioning of the practice, but is not specifically required by the City of Inver Grove Heights.
RECOMMENDED:	Indicates design guidance that is helpful for performance but not critical to the design.

Design Variants

There are two types of green roofs, extensive and intensive, composed of the same system of layers. Buildings may have a combination of extensive and intensive areas on the same roof.

Extensive Use Green Roof – Extensive systems are lighter, typically have 4 inches or less of growing medium, use drought tolerant vegetation, and can structurally support limited uses (such as maintenance personnel).

Intensive Use Green Roof – Intensive systems are heavier, have a greater soil depth, can support a wider range of plants, and can support increased pedestrian traffic and recreational use. In reality, there are varying degrees of intensive green roofs, ranging from fully intensive uses such as miniature golf to semi-intensive uses that integrate walking paths and passive recreation.

Retrofit Suitability

Green roof retrofits are possible depending on the structural support offered by the existing building. An engineer experienced in green roof retrofits should be used to assure that the structure is suitable. Green roofs are highly desirable as retrofit practices in watersheds that are concerned about water temperature, runoff volume and runoff rates.

Cold Climate Suitability

Care must be taken to ensure that plants are correctly selected for green roofs. They must be hardy and winter tolerant. Using native plants increases the likelihood of plant survival. Some green roofs may be able to house evergreens, creating a year-round green roof. See the planting guide in Appendix B for species that will work well in Inver Grove Heights.

Water Quantity Treatment

The amount of stormwater volume reduction depends on the green roof configuration. Green roofs reduce volume through rainfall interception on plant surfaces, evaporation or transpiration. Green roofs can also be designed to have depressional storage incorporated into the landscape, increasing the holding capacity of the roof and providing water for plants during dry periods.

In general, supplemental stormwater practices will be necessary to satisfy the volume control requirements when green roofs are used. However, these practices can help reduce retention requirements for a site through volume reduction. Larger green roofs have the potential to provide greater water quantity benefits due to their size.

Water Quality Treatment

Monitoring data on green roof runoff is limited but a Swiss study (Berdtsson-Bengtsson, 2005), indicates that green roofs act as a source for phosphorus and a sink for nitrogen. Surcharge storage above the green roof outlet is available for detention. Utilizing this detention can lower peak discharges from the roof. Outlet structures can be sized to partially or fully accommodate larger storm peak discharge control while allowing the volume below the outlet to be used by the vegetation at a later time. This detention can decrease peak flows in downstream waterways.

Green roofs can also remove atmospheric pollutants through filtration, soil adsorption, and biological uptake. Surface water load reductions are also realized by virtue of the reduction in runoff volume. Because green roofs do not get as hot in the summer, the runoff leaving a green roof can be expected to be cooler then the runoff leaving a conventional roof. A pollutant removal table is not provided due to the variability of green roofs and the limited monitoring data available.

Limitations

The following general limitations should be recognized when considering installation of a green roof:

- ► Limited monitoring data are available
- ► Failure can occur due to improper siting, design, construction and maintenance
- ► Cost is higher than traditional roofing ($14-$25 /ft^2, Greenroofs.com)
- ► Leaks can be hard to locate and repair without an electronic leak detection system
- ► Conditions can be harsh for vegetation establishment
- ► Maintenance needs can be higher than traditional roofing system

B. Major Design Elements

Physical Feasibility Initial Check

Before deciding to use green roofs for stormwater management, it is helpful to consider several items that bear on the feasibility of using such a device at a given location. The following list of considerations will help in making an initial judgement as to whether or not a green roof is the appropriate BMP for the site.

- ► Structural support – The structure should be able to support the additional weight of a green roof. An extensive green roof is relatively lightweight and generally within the normal load-bearing capacity of modern roof structures. Intensive green roofs vary greatly in weight but will need to be considered in structural design. A structural engineer must certify the existing or proposed structure.
- ► Accessibility – The green roof should not obstruct maintenance personnel and should be built only on roofing surfaces, not on mechanical components.
- ► Soils – It is HIGHLY RECOMMENDED that engineered soils be used. Engineered soils are lighter and have consistent characteristics desirable for roofing. Under the supervision of a structural engineer and/or landscape architect, topsoil can be used or incorporated into the engineered soil.

Conveyance

The first part of stormwater is received on plant surfaces. Once the initial abstractions from plant surfaces are saturated, green roof conveyance starts by infiltrating stormwater through the growing media. Stormwater is then conveyed through a drainage media (porous or granular material) to a drain at the edge of the roof. Water that is not retained within the plant surfaces, soil media or drainage media is conveyed to further stormwater systems via a downspout.

Pretreatment

- ► Green roofs require no pretreatment but can act as a pretreatment practice for small impervious areas on the roof. (HVAC systems, walkways, etc.)

Treatment

The following guidelines are applicable to the actual treatment area of a green roof.

- ► Space Occupied – Generally the entire rooftop, but partial rooftop installations are possible
- ► Practice Slope – Slope of roof. The practical maximum slope of a green roof is 30 percent. It is possible to create green roofs on steeper slopes but additional slippage control may need to be used.
- ► Depth – The soil depth of a green roof can range from 3” in extensive green roofs to 18” for intensive green roofs. The depth is dependent on the type of vegetation to be planted and the intent of use.
- ► Aesthetics – Green roofs can be effectively integrated into the site planning process, and aesthetically designed as attractive green spaces planted with native vegetation. Generally, all green roofs serve environmental and economical benefits while providing an aesthetic amenity.

Landscaping

- It is REQUIRED that the roof be established with dense and healthy vegetation as soon as possible after the growing medium is deposited.
- It is HIGHLY RECOMMENDED that vegetation on green roofs be regularly maintained and bare areas seeded.
- It is HIGHLY RECOMMENDED that green roofs are provided an irrigation system. Regular watering is REQUIRED during the establishment of vegetation. Using a rainwater harvesting system is a common way to provide irrigation water for a green roof.

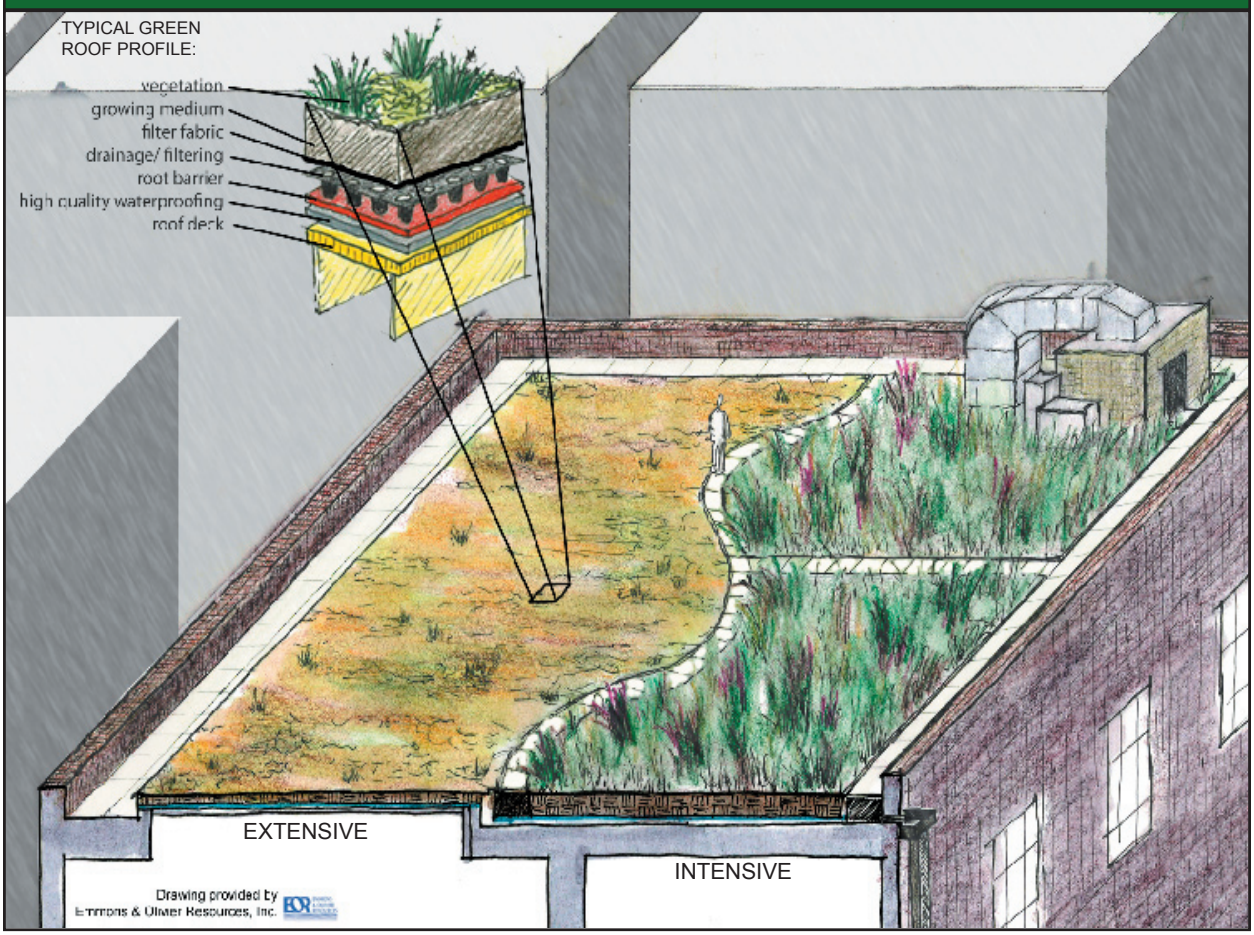
Safety

- Many roof safety measures that apply to conventional roofing also apply to green roofs.
- OSHA health and safety guidelines should be followed for safe construction practices. Additional information on safety for construction sites is available from OSHA. Use the following link to research safety measures for construction sites: http://www.osha.gov/pls/oshaweb/

C. Construction Details

Because of the proprietary nature of green roofs, no construction details are provided. Rather, the components of a typical green roof are shown in Figure 8.2.

Figure 8.2 Typical Intensive and Extensive Green Roofs



Courtesy of Rice Creek Watershed District

D. Construction Specifications

Construction of green roofs incorporates techniques or steps which may be considered non-standard; it is RECOMMENDED that an engineer experienced in green roof construction be contracted for the final design plans and specifications. Table 8.9 identifies a majority of the green roof components, function, and level of necessity.

I. Temporary Erosion Control
- ► Installation prior to site disturbance
- ► Catch basin/inlet protection
- ► Secure media with erosion control mat

II. Equipment, Transportation, and Components
- ► Timing of green roof construction (relative to total site development)
- ► Use of light weight equipment suitable for rooftop work
- ► Conveyor, elevator or blower to transport media to the roof
- ► Restoration in the event of disturbance during construction of practice
- ► Underdrain specifications
- ► Waterproofing specifications

III. Native Plants, Planting and Transplanting (MN Plant List in Appendix B of the Manual, ASTM Green Roof Standard 2400)
- ► Site preparation of planting areas
- ► Timing of native seeding and native planting
- ► Watering of plant material
- ► Weed control

IV. Construction Sequence Scheduling
- ► Priming deck
- ► Insulation
- ► Waterproofing Layer
- ► Leak Test
- ► Filter fabric
- ► Irrigation system
- ► Growing Medium
- ► Seed and Plant
- ► Installation of semi-permanent and permanent erosion control measures

V. Construction Observation
- ► Adherence to construction documents
- ► Continual site management
- ► Verification of physical site conditions
- ► Erosion control measures installed appropriately
- ► Completion of Construction

Table 8.9 Green Roof Components

Component	Function	Description	Necessity
High quality waterproofing	Prevents water from entering the building	Impervious concrete, liquid membranes, 1-ply sheets, multiple layers	Required
Root repellent system	Prevents unwanted plants from compromising the waterproofing	Metal, poured concrete	Required
Drainage and filtering	Drains growth media to prevent drowning	Porous mats, granular media, polystyrene, coconut mats, plastics	Required
Growing medium	Plant survival, stormwater retention, habitat	Engineered soils with a mixture of organic and inorganic matter	Required
Vegetation	Aesthetics, insulations, stormwater management	Perennials, biennials or annuals, non-aggressive roots	Required
Insulation	Energy savings, protect plant roots	Vegetable fiber, glass fiber, polystyrene foam, other foams	Recommended
Membrane protection cloth	Protect membranes from construction stress	Polyester fiber mats, non-woven landscape fabric	Recommended
Leak detection system	Ensure waterproofing, easily locate leaks	Electronic Field Vector Mapping is an electronic leak detection system	Recommended
Ponds and pools	Aesthetics, stormwater management	Waterfalls, fountains, ponds	Optional
Irrigation system	Ensures plant survival	Overhead, surface drip, capillary, base drip, or trickle	Optional
Walkways	Accessibility, pedestrian flow control	Numerous types of walkways are suitable	Optional
Curbs and borders	Aesthetics	Numerous types of curbs and borders are suitable	Optional
Railings	Protect people from falls, Aesthetics, limit access	Numerous types of railings are suitable	Optional
Lighting	Aesthetics, night time use, security	Numerous types of lighting is suitable	Optional

Source: Adapted from GRHC 2004

E. Operation and Maintenance

Overview

Effective long-term performance of green roofs requires a green roof management plan (HIGHLY RECOMMENDED), performance monitoring (HIGHLY RECOMMENDED), and a dedicated and routine maintenance schedule with clear guidelines and schedules (REQUIRED).

The green roof management plan (operation plan) should address the following items: vegetation management (feeding, plant protection, drainage and weeding), wet/dry cycling of soils, and dewatering procedure. The monitoring plan should address the following items: inspection and efficiency assessment, water quality and quantity monitoring of runoff leaving the roof, and plant tolerances.

Construction and Maintenance Costs

Table 8.10 is a list of the general components used in construction of this practice. Utilizing Table 8.10 will allow designers to avoid over or under estimation of fixed costs.

Table 8.10 Green Roof Cost Components

Implementation Stage	Primary Cost Components	Basic Cost Estimate
Structural Components	Electronic Leak Detection System	($/square yard)
	Outflow components	($/structure)
	High Quality Waterproofing	($/square yard)
	Root Barrier	($/square yard)
	Drainage/Filtering Media	($/square yard)
	Filter Fabric	($/square yard)
	Growing Media	($/cubic yard)
	Vegetation	($/square yard of seed and mulch) or ($/plant)
	Overflow weir/baffle	($/structure)
Annual Operation, Maintenance, and Inspection	Weeding	Removal Cost ($/acre) x Area (acre) x Frequency (1x / 5yr)
	Watering	($/gallon)
	Inspection	Inspection Cost ($) x Inspection Frequency (6x / 1 yr)
	Mowing (for some green roofs)	Mowing Cost ($) x Mowing Frequency (6x / 1 yr)

F. Design Procedure

Because of the proprietary nature of green roofs, a design procedure is not provided.

G. Additional Resources

Berndtsson, J.C., Bengtsson, L., 10th International Conference on Urban Drainage, Copenhagen/Denmark. The Influence of Extensive Vegetated Roofs on Runoff Water Pollution Loads. August 2005.

Georgia Stormwater Management Manual. 2001. Atlanta Regional Commission. http://www.georgiastormwater.com/

Greenroofs.com Contains: Green Resource News, Upcoming events, recommended readings, latest news about green roofs including projects and research links. http://www.greenroofs.com/

Greenroofs.org Contains: Official website of Green Roofs for Healthy Cities. Information about green roofs, installation, benefits and demonstration projects. http://www.greenroofs.org/ .

Green Roofs for Healthy Cities (GRHC) Green Roof Design 101 Course Participant Manual. June 2004.

Minnesota Pollution Control Agency. The Minnesota Stormwater Manual. 2005. http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html#manual

RoofScapes Inc. http://www.roofmeadow.com/

Vermont Stormwater Management Manual. 2002. http://www.vtwaterquality.org/stormwater.htm.

Wisconsin DNR Site Evaluation for Stormwater Infiltration Conservation Practice Standard 1002. 2004. http://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm#Post.

Wisconsin DNR Infiltration Basin Conservation Practice Standard 1003. 2004. http://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm#Post.

RAINWATER HARVESTING

Residential rain barrel - Stillwater, MN

Definition:
Rain water harvesting is the practice of collecting rain water from impermeable surfaces, such as rooftops, and storing for future use. There are a number of systems used for the collection, storage and distribution of rain water including rain barrels, cisterns, evaporative control systems, and irrigation.

KEY CONSIDERATIONS

Design Criteria:

- The system should be watertight, have a smooth interior surface, be located on level and stable ground, have a tight-fitting lid, good screens on the inlet and outlet and have an emergency overflow device.
- To prevent the breeding of mosquitoes, empty the water in less than 5 days or place a fine screen over all openings.
- Material can withstand the pressure of water over long periods of time.
- Disconnect and drain rain barrels and cisterns in the winter to prevent freezing and deformation of the rain water harvesting system.

Benefits:

- Protects water supplies by reducing use during peak summer months.
- Mimics the natural hydrology of the area by infiltrating a portion of the rain water falling on the site.
- Reduces volume of storm water being delivered to downstream waterbodies.
- Results in cost savings by reducing municipal water bill.

Limitations:

- Not suitable for the following roof types: tar and gravel, asbestos shingle and treated cedar shakes.
- Depending on the design, requires a certain amount of operation and maintenance.
- Proprietary systems can be expensive.

MANAGEMENT SUITABILITY

X	Volume Control
X	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
X	Wetland Bounce

MECHANISMS

X*	Infiltration
X*	Screening/ Filtration
X	Temperature Control
X	Settling
X	Evaporation
X*	Transpiration
X*	Soil Adsorption
X*	Biological/ Micro. Uptake

POLLUTION REMOVAL

100%*	Total Suspended Solids
100%*	Nutrients - Total Phosphorus/ Total Nitrogen
100%*	Metals - Cadmium, Copper, Lead, and Zinc
100%*	Pathogens - Coliform, Streptococci, E. Coli
100%*	Toxins - Chloride, Hydrocarbons, Pesticides

**Assuming water is drained to a vegetated pervious area. Does not apply to volume of runoff that bypasses the system*

SITE FACTORS

Rooftop	Drainage Area
NA	Max. Slope
NA	Min. Depth to Bedrock
NA	Min. Depth to Water Table
NA	SCS Soil Type *can be used in C&D soil types with modifications (e.g. underdrains)
Poor	Freeze/ Thaw Suitability
Suitable	Potential Hotspot Runoff

Description:
Rain water harvesting can be accomplished using rain barrels and/or cisterns. Rain barrels are typically located at the downspout of a gutter system and are used to collect and store rainwater for watering landscapes and gardens. The simplest method of delivering water is by the force of gravity. However, more complex systems can be designed to deliver the water from multiple barrels connected in a series with pumps and flow control devices. Cisterns have a greater storage capacity than rain barrels and may be located above or below ground. Due to their size and storage capacity, these systems are typically used to irrigate landscapes and gardens on a regular basis reducing the strain on municipal water supplies during peak summer months. Again, cisterns may be used in series and water is typically delivered using a pump system. The storage capacity of a rain barrel or cistern is a function of the catchment area, the depth of rainfall required to fill the system and the water losses. A general rule of thumb in sizing rain barrels or cisterns is that one inch of rainfall on a 1,000 square foot roof will yield approximately 600 gallons of runoff.

A. Suitability

General

Rain water harvesting is the practice of collecting rain water from impermeable surfaces, such as rooftops, and storing for future use. There are a number of systems used for the collection, storage and distribution of rain water but they generally fall into two categories; rain barrels and cisterns.

Function Within Stormwater Treatment Train

Rain water harvesting is one of the first steps in the treatment train. It can be designed to provide stormwater reduction and detention. The practice may be applied as part of a stormwater management system to achieve the following objectives:

- reduce stormwater pollutants
- decrease runoff peak flow rates
- decrease the volume of stormwater runoff

Inver Grove Heights Permit Applicability

One of the goals of this manual is to facilitate an understanding of and compliance with the City of Inver Grove Heights' volume control standard. This standard must be met on all new and re-development projects taking place in the northwest area.

Storage should be provided so that rainfall is collected and stored and then released during periods of dry weather. Volume reduction may be applied to the 5-year 24-hour standard for the total volume that can be stored. An operation and maintenance plan must be approved by the city engineer to ensure that the volume is available for most runoff events.

The following terms are thus used in the text to distinguish various levels of rainwater harvesting design guidance:

REQUIRED:	Indicates design standards stipulated by the IGH PUD.
HIGHLY RECOMMENDED:	Indicates design guidance that is extremely beneficial or necessary for proper functioning of the practice, but is not specifically required by the City of Inver Grove Heights.
RECOMMENDED:	Indicates design guidance that is helpful for performance but not critical to the design.

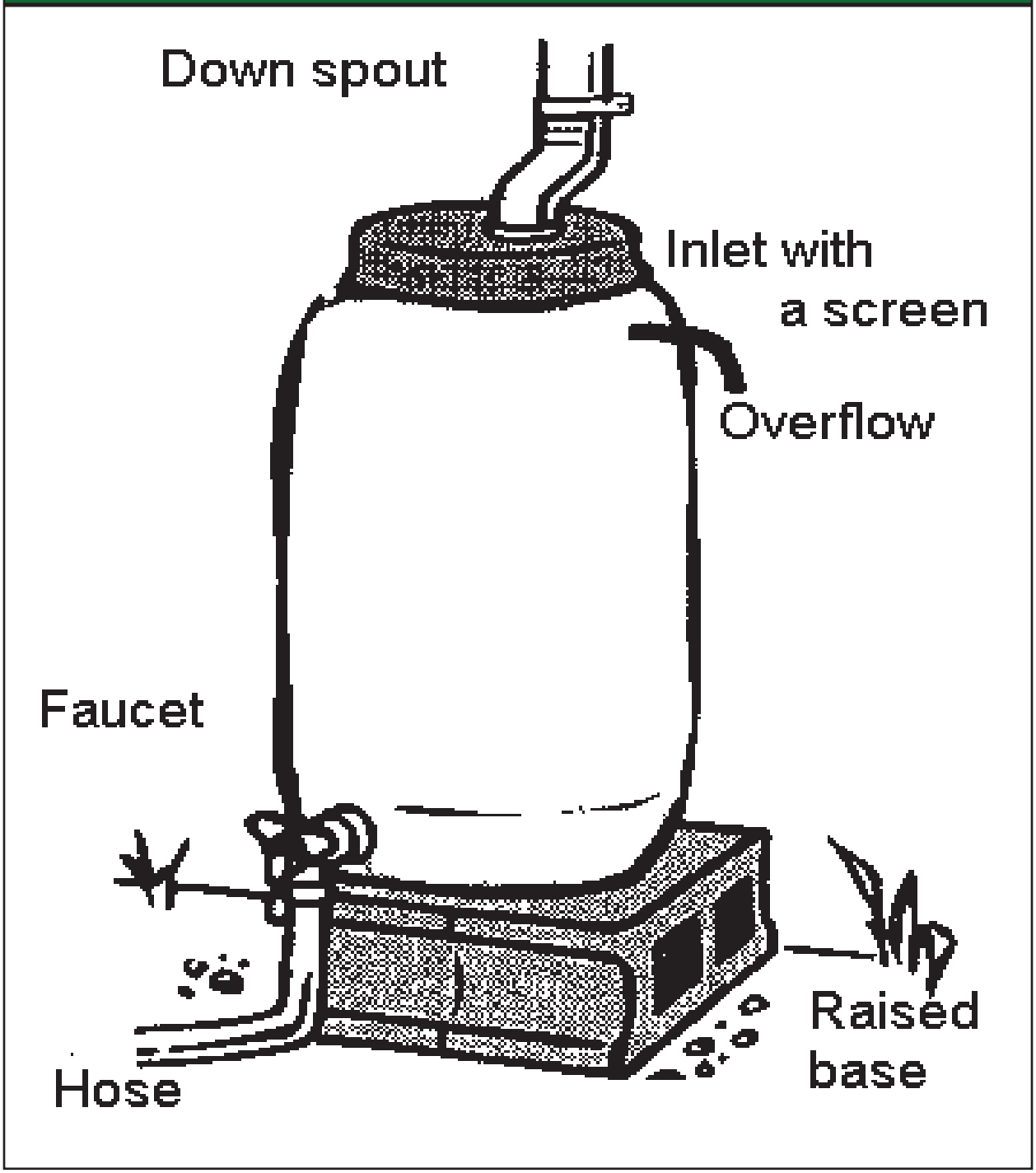
Design Variants

Rain water harvesting can be accomplished using rain barrels and/or cisterns.

Rain Barrel

Rain barrels are typically located at the downspout of a gutter system and are used to collect and store rainwater for watering landscapes and gardens. The simplest method of delivering water is by the force of gravity. However, more complex systems can be designed to deliver the water from multiple barrels connected in a series with pumps and flow control devices. A typical rain barrel is shown in Figure 8.3.

Figure 8.3 Typical Rain Barrel Design

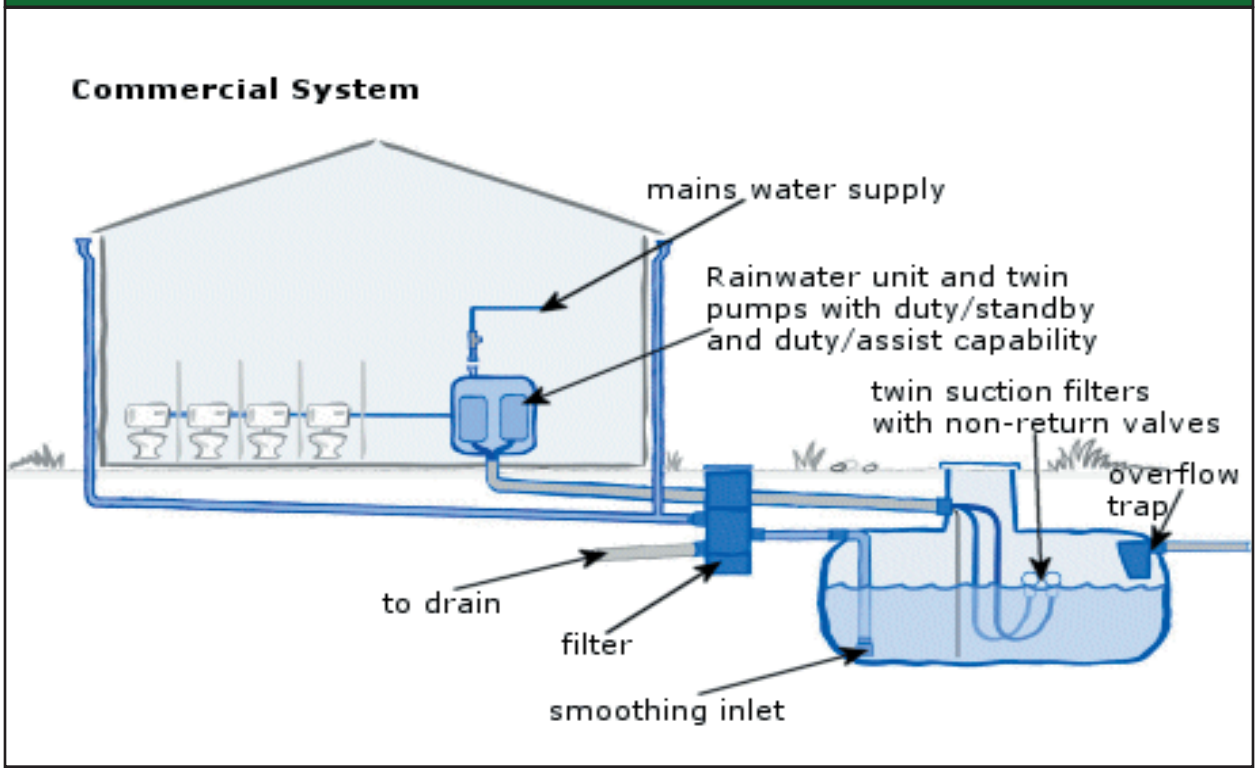


Source: Ottawa City Services

Cistern

Cisterns have a greater storage capacity than rain barrels and may be located above or below ground. Due to their size and storage capacity, these systems are typically used to irrigate landscapes and gardens on a regular basis reducing the strain on municipal water supplies during peak summer months. Again, cisterns

Figure 8.4 Typical Cistern Design



Source: Rainwater Harvesting Systems, Inc.

may be used in series and water is typically delivered using a pump system. A typical cistern is shown in Figure 8.4.

Retrofit Suitability

Rainwater harvesting retrofits are easily applied to existing buildings. Rain water harvesting is a highly desirable retrofit practice in watersheds that are concerned about reducing water quantity.

Cold Climate Suitability

Rainwater harvesting is suitable for cold climates but some systems can only be used in summer conditions. Disconnect and drain rain barrels and cisterns in the winter to prevent freezing and deformation of the rain water harvesting system.

Water Quantity Treatment

The amount of stormwater volume reduction depends on the rainwater harvesting configuration and the rate of use. Rain water harvesting reduces volume by capturing runoff from impervious areas, generally rooftops.

In general, supplemental stormwater practices will be necessary to satisfy the volume control requirement when rain water harvesting is used. However, these practices can help reduce the overall volume that requires treatment.

Water Quality Treatment

When stormwater is harvested and applied to a pervious vegetative surface, it removes pollutants through filtration, soil adsorption, and biological uptake. Surface water load reductions are also realized by virtue of the reduction in runoff volume. Pollutant removal data for select parameters is provided in Table 8.11.

Table 8.11. Percent Removal of Key Pollutants by Rain Water Harvesting

Practice	TSS [%]	Total Phosphorus [%]	Total Nitrogen [%]	Metals [%]	Bacteria [%]	Hydro-carbons [%]
Rain water harvesting	100*	100*	100*	100*	100*	100*

Notes
* If water is drained to a vegetated area. Does not apply to volume of runoff that bypasses the system

Source: MPCA, 2005

Limitations

The following general limitations should be recognized when considering installation of a rainwater harvesting system:

- Not suitable for the following roof types; tar and gravel, asbestos shingle and treated cedar shakes.
- Depending on the design, requires a certain amount of operation and maintenance.
- Proprietary systems can be expensive.

B. Major Design Elements

Physical Feasibility Initial Check

Before deciding to use rainwater harvesting for stormwater management, it is helpful to consider several items that bear on the feasibility of using such a device at a given location. The following list of considerations will help in making an initial judgement as to whether or not a rainwater harvesting technique is the appropriate BMP for the site.

- ***Drainage Area*** – Rooftop
- ***Site Topography and Slopes*** – NA
- ***Soils*** – NA
- ***Depth to Ground Water Table and Bedrock*** – NA
- ***Site Location / Minimum Setbacks*** – consider routing overflow away from building foundation
- ***Karst*** – NA

Conveyance

Stormwater is conveyed to the rainwater harvesting system by a downspout. The system fills to capacity and excess water is released by an overflow outlet. Water is removed from the storage chamber by a pump or gravity drain. An overflow should be provided for storms that exceed the design storm.

Pretreatment

- Rain water harvesting systems should have a screen at the end of the downspout to prevent clogging.

Treatment

The following guidelines are applicable to the actual treatment area of the rainwater harvesting device.

- ***Space Occupied*** – Large installations can be underground. Small residential units are generally above ground and space is dictated by the amount of runoff expected to be collected.
- ***Practice Slope*** – NA
- ***Side Slopes*** – NA
- ***Depth*** – NA
- ***Groundwater Protection*** – NA
- ***Aesthetics*** – Rain barrels can be designed to be aesthetically pleasing and come in many different styles. Rain water harvesting can also be effectively integrated into the site planning process to be unseen (underground) or can be surrounded by vegetation to be inconspicuous.

Landscaping

- Rain water harvesting is often used as the water source for gardens, lawns and landscaping features. Harvested water can also be used for a water feature such as a fountain.

Safety

- If maintained or designed poorly a rain barrel can act as a breeding ground for mosquitoes. Rain barrels should be drained within 5 days to prevent mosquito breeding grounds. Rain barrels fitted with a screen may not need to be drained as often provided that the mesh pattern is fine enough to prevent mosquito entry.
- Water from rainwater harvesting systems should not be used directly on consumable vegetables because of the risk of contamination from bird dropping on roofs, and toxins from roofing materials.
- Rain barrels should have a locking lid to prevent children and animals from entering and drowning.

C. Construction Specifications

Construction of rain water harvesting practices incorporates techniques or steps which may be considered non-standard; it is RECOMMENDED that for cisterns a contractor experienced in rainwater harvesting construction be contracted for the final design plans and specifications. It is generally not necessary to hire a contractor for small residential systems.

D. Operation and Maintenance

Overview

Effective long-term performance of rain water harvesting requires a dedicated and routine maintenance schedule with clear guidelines and schedules (REQUIRED). An operating plan must be filed with the city before stormwater reduction credit will be received. Operating plans should include the maximum time that water will be stored, type and size of area that the water will be used, and location of the emergency overflow.

Construction and Maintenance Costs

Table 8.12 is a list of the general components used in construction of this practice. Utilizing Table 8.12 will allow designers to avoid over or under estimation of fixed costs.

Table 8.12 Rainwater Harvesting Cost Components		
Implementation Stage	**Primary Cost Components**	**Basic Cost Estimate**
Structural Components	Downspouts	($/structure)
	Screening	($/structure)
	Piping	($/structure)
	Pumps	($/structure)
	Storage Chambers	($/structure)
	Valves, hoses	($/structure)
	Lid and locking mechanism	($/structure)
Annual Operation, Maintenance, and Inspection	Removing Sediments	Removal Cost
	Cleaning Screens	($/screen)
	Winterizing system	($/year)
	Pump Maintenance (cisterns only)	($/year)

E. Links to Other Manuals

Georgia Stormwater Management Manual. 2001. Atlanta Regional Commission.
http://www.georgiastormwater.com/

Vermont Stormwater Management Manual. 2002.
http://www.vtwaterquality.org/stormwater.htm.

Wisconsin DNR Site Evaluation for Stormwater Infiltration Conservation Practice Standard 1002. 2004.
http://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm#Post.

Wisconsin DNR Infiltration Basin Conservation Practice Standard 1003. 2004.
http://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm#Post.

Minnesota Pollution Control Agency. The Minnesota Stormwater Manual. 2005.
http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html#manual

F. References

Center for Disease Control. Stormwater Management and Vector Breeding Habitats.
http://www.cdc.gov/nceh/ehs/Docs/Stormwater-Factsheet.pdf

Pamela Shubat. Minnesota Department of Health, 2006

Ottawa City Services. How to make your own rain barrel.
http://www.ottawa.ca/city_services/water/efficiency/rain_barrel_en.shtml

Rainwater Harvesting Systems, Inc UK Rainwater Harvesting Association
http://www.rainharvesting.co.uk/systems/commercial.htm Accessed Online June 27, 2006

PERVIOUS SURFACES

Grasspave® at Bradshaw Celebration of Life Center - Stillwater, MN

Definition:
Pervious pavements reduce the amount of runoff by allowing water to pass through surfaces that would otherwise be impervious. Water can either infiltrate into the ground, if soil permeability rates allow, or be conveyed to other BMPs or a storm water system by an under-drain.

KEY CONSIDERATIONS

Design Criteria:

- Pervious pavement is typically used in low traffic areas including overflow parking areas, emergency vehicle lanes, and pedestrian areas.
- In-situ soils should have field-verified minimum permeability rates greater than 0.3 in./hr. Contributing runoff from offsite should be limited to a 3:1 ratio of impervious area to pervious pavement area.
- The selected systems load bearing surface should be suited to maximum intended loads.
- Design storms should be infiltrated within 72 hours (48 hours to meet MPCA requirements)

Benefits:

- Good for highly impervious areas – particularly parking lots.
- Reduces need for other storm water BMPs by reducing runoff.
- Construction costs of some systems are less than traditional paving.
- Soil-enhanced turf systems resist compaction, increase infiltration, and provide soils for healthier vegetation.

Limitations:

- Construction costs of some systems are more expensive than traditional paving
- Use depends on infiltration rates of underlying soils.
- Maintenance costs are higher than conventional paving.
- Not recommended for high traffic areas because of durability concerns.

MANAGEMENT SUITABILITY

X	Volume Control
X	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
X	Wetland Bounce

MECHANISMS

X*	Infiltration *with appropriate site conditions
X	Screening/ Filtration
X	Temperature Control
	Settling
	Evaporation
X*	Transpiration *if vegetation present
X	Soil Adsorption
X	Biological/ Micro. Uptake

POLLUTION REMOVAL

NA*	Total Suspended Solids *pretreatment for TSS is recommended if adjacent areas drain to pervious pavement
80%/ 80%	Nutrients - Total Phosphorus/ Total Nitrogen
90%	Metals - Cadmium, Copper, Lead, and Zinc
NA	Pathogens - Coliform, Streptococci, E. Coli
NA	Toxins - Chloride, Hydrocarbons, Pesticides

Note: Pollution removal percentages apply to volume of runoff treated, and not to volume of runoff bypassed

SITE FACTORS

NA	Drainage Area
2% Max.	Max. Slope
3 ft	Min. Depth to Bedrock
3 ft	Min. Depth to Water Table
A,B	SCS Soil Type *can be used in C&D soil types with modifications (e.g. underdrains)
Good	Freeze/ Thaw Suitability *with adequate sub-grade
Yes	Potential Hotspot Runoff *requires impermeable liner if identified in hotspot area

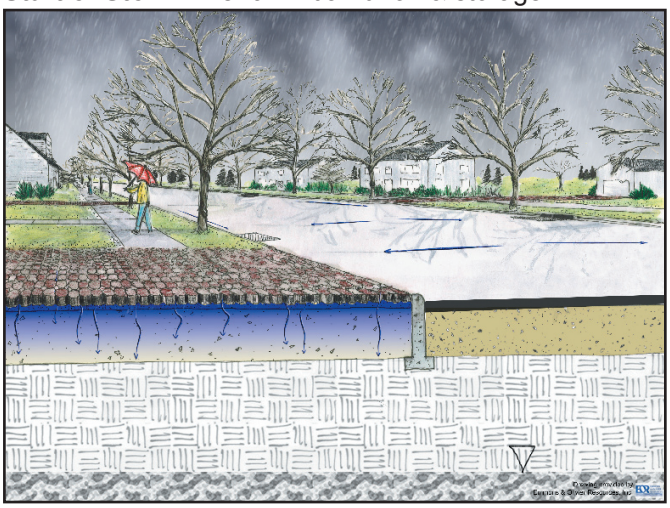
Description:
Pervious pavements can be subdivided into three general categories: 1) **Porous Pavements** – porous surfaces that infiltrate water across the entire surface (i.e. porous asphalt and porous concrete pavements); 2) **Permeable Pavers** – impermeable modular blocks or grids separated by spaces or joints that water drains through (i.e. block pavers, plastic grids, etc.); 3) **Amended Soils** - Fiber or artificial media added to soil to maintain soil structure and prevent compaction. There are many different types of modular porous pavers available from different manufacturers.

Pervious pavement systems reduce runoff from impervious surfaces by allowing stormwater to pass through the load bearing surface and infill that are selected based upon the intended application and required infiltration rate. Runoff is stored in the stone aggregate base course/ storage layer, if present, and allowed to infiltrate into the surrounding soil (functioning like an infiltration basin), or collected by an under-drain system and discharged to the storm sewer system or directly to receiving waters (functioning like a surface sand filter).

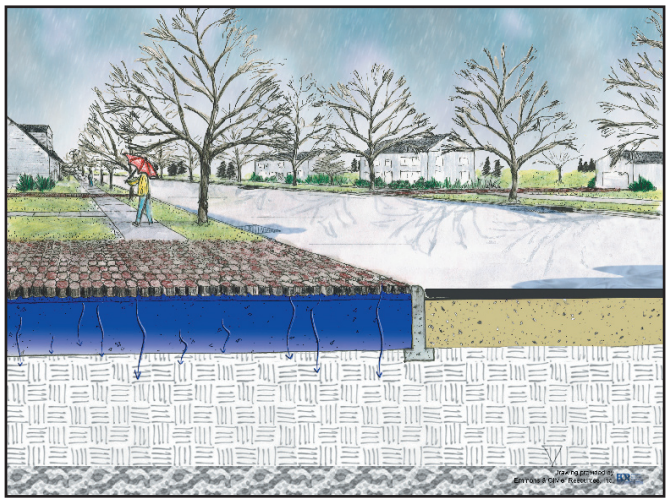
Regular maintenance of pervious pavements is necessary to ensure long-term effectiveness. Annual or semi-annual sweeping or vacuuming of surface debris (litter, sediment, etc.) is HIGHLY RECOMMENDED for pavement or pavers. If clogging occurs, the filtration media below the surface may need to be replaced. Manufacturers should be consulted for specific maintenance requirements.

STORM SEQUENCE

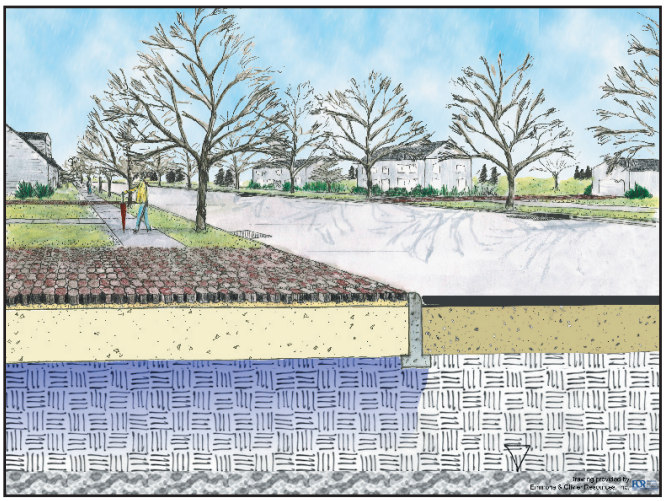
Start of Storm Event - Initial runoff & storage



Duration of Storm Event - Storage & filtration/infiltration



Following Storm Event - Remaining storage draw-down



Courtesy of Rice Creek Watershed District

A. Suitability

General

Pervious surfaces reduce the amount of stormwater runoff generated on a site by allowing water to pass through surfaces that would otherwise be impervious. Water can either infiltrate into the ground, if soil permeability rates allow, or be conveyed to other BMPs or a storm water system via an under-drain.

Some types of pervious surfaces may work well on residential and arterial roads but generally pervious surfaces are used in areas with low traffic loads. The most popular applications of pervious surfaces are:

- Overflow parking for commercial sites
- Private roads and driveways
- Intermittently used facilities that require large parking areas (churches, stadiums, auditoriums)
- Emergency vehicle lanes

Function Within Stormwater Treatment Train

Pervious surfaces are one of the first steps in the treatment train. They can be designed to provide stormwater reduction, detention and cooling. The practice may be applied as part of a stormwater management system to achieve the following objectives:

- reduce stormwater pollutants
- decrease runoff peak flow rates
- decrease the volume of stormwater runoff

Inver Grove Heights Permit Applicability

One of the goals of this manual is to facilitate an understanding of and compliance with the City of Inver Grove Heights' volume control standard. This standard must be met on all new and re-development projects taking place in the northwest area.

Where additional hard surface is desired such as an additional parking space near the garage or where a turn around/guest parking space is desired it must be of permanent pervious surface such as brick pavers, pervious concrete/asphalt or other technique as approved through the City of Inver Grove Heights Stormwater Manual (Subd. 39 H.3.a)

Where possible, pervious surfaces should be designed for volume control. Storage should be provided below the pervious surface in the form of gravel or other underground storage medium. Volume reduction may be applied to the 5-year 24-hour standard for any storage provided below the underground storage overflow elevation. Additionally, volume credit may be allowed for different configurations of pervious surfaces but the amount of volume credit will be based on substrate properties, paver layout, and other properties and will need to be approved by the city engineer.

The following terms are thus used in the text to distinguish various levels of pervious surface design guidance:

REQUIRED:	Indicates design standards stipulated by the IGH PUD.
HIGHLY RECOMMENDED:	Indicates design guidance that is extremely beneficial or necessary for proper functioning of the practice, but is not specifically required by the City of Inver Grove Heights.
RECOMMENDED:	Indicates design guidance that is helpful for performance but not critical to the design.

Design Variants

Pervious surfaces can be subdivided into three general categories:

1) ***Porous Pavements*** – porous surfaces that absorb water across the entire surface (i.e. porous asphalt and porous concrete pavements);

2) ***Permeable Pavers*** – impermeable modular blocks or grids separated by spaces or joints that water drains through (i.e. block pavers, plastic grids, etc.). There are many different types of modular porous pavers available from different manufacturers.

3) ***Reinforced Soil*** - Fiber or artificial media added to soil to maintain soil structure and prevent compaction. Generally a structural matrix made of plastic or metal that absorbs the weight of vehicles and pedestrians and leaves the soil uncompacted. This variant does not include amending soils with mulch or other organics, for more information on amended soils see the soil amendment section in this chapter.

Retrofit Suitability

Pervious surface retrofits are popular when an existing impervious surface will be upgraded or replaced. They also provide a great option for expanding parking lots that are intermittently used.

Cold Climate Suitability

The freeze/thaw suitability of pervious surfaces is as good as conventional pavement as demonstrated by the many successful examples throughout the twin cities.

Water Quantity Treatment

The amount of stormwater volume reduction depends on the pervious surface configuration. Pervious surfaces can be designed to reduce volume through infiltration if the underlying soils permit.

In general, supplemental stormwater practices will likely be necessary to satisfy volume control requirements when pervious surfaces are used. However, these practices can help reduce volume requirements for a site through volume reduction and retention.

Pervious surface systems reduce runoff from impervious surfaces by allowing stormwater to pass through the load bearing surface and infill that are selected based upon the intended application and required infiltration rate. Runoff is stored in the stone aggregate base/storage layer, if present, and allowed to infiltrate into the surrounding soil (functioning like an infiltration basin), or collected by an under-drain system and discharged to the storm sewer system or directly to receiving waters (functioning like a surface sand filter).

Water Quality Treatment

Pervious surfaces can remove stormwater pollutants through chemical and bacterial degradation, sorption, and filtering. Surface water load reductions are also realized by virtue of the reduction in runoff volume. Due to the logistical challenges presented in structuring a runoff quality study, the number of scientific studies documenting the pollutant removal capability of pervious surfaces is limited. However, pollutant removal and effluent concentration data for select parameters are provided in Table 8.13.

Table 8.13. Percent Removal of Key Pollutants by Practices

Practice	TSS [%]	Total Phosphorus [%]	Total Nitrogen [%]	Metals [%]	Bacteria [%]	Hydro-carbons [%]
Pervious Surfaces	NA*	80	80	90	ND	ND

Notes
* Pretreatment for TSS is recommended if adjacent areas drain to pervious surfaces
ND: No Data

Source: Winer, 2000

Limitations

The following general limitations should be recognized when considering installation of a pervious surface system:

- Not recommended for high traffic areas
- Construction costs of some systems are more expensive than traditional paving
- Ability to use it for stormwater volume reduction credit depends on infiltration rates of underlying soils
- Maintenance needs can be higher than conventional paving

B. Major Design Elements

Physical Feasibility Initial Check

- ***Site Topography and Slopes*** – 2% maximum slope to allow adequate time for absorption.
- ***Soils*** – Underlying soils should be HSG A or B for infiltration designs. C and D soils are sufficient if infiltration is not a priority.
- ***Depth to Ground Water Table and Bedrock*** – Minimum 3 feet from bottom of the practice to the seasonally high water table or bedrock.

Conveyance

It is HIGHLY RECOMMENDED that a pervious surface system have slopes less than 2% and underlying soils that have field verified infiltration rates of 0.3 in/hour or greater. These criteria allow the water to be conveyed vertically to recharge groundwater. When excessive rainfall beyond the capabilities of the underlying soils occurs, water should drain to additional BMPs or offsite to a stormwater management system.

Pretreatment

- Routing water from adjacent impervious areas to pervious surfaces will be allowed if approved by the city engineer. Water routed to pervious surfaces from other impervious areas requires pretreatment for TSS or city approval. Contributing runoff from offsite should be limited to a 3:1 ratio of impervious area to pervious surface area.

Treatment

- ***Space Occupied*** – Parking areas, roads, driveways and patios are the most common spaces occupied by pervious surfaces. Regularly used for retrofits because it utilizes existing space.
- ***Practice Slope*** – <2%
- ***Side Slopes*** – NA
- ***Depth*** – Variable based on site soils, depth of aggregate and type of surface used.
- ***Groundwater Protection*** – It is required that runoff from potential stormwater hotspots not be infiltrated unless adequate pre-treatment has been provided. Infiltration of runoff from confirmed hotspot areas, industrial areas with exposed significant materials or vehicle fueling and maintenance areas is PROHIBITED.
- ***Aesthetics*** – Pervious surfaces can be integrated into the site planning process, and aesthetically designed using decorative pavers. Or they can be designed to look similar to conventional paving systems.

Landscaping

- Depressed parking lot islands are an aesthetic and functional compliment to pervious surface parking lots.
- It is HIGHLY RECOMMENDED that vegetation surrounding pervious surfaces be regularly maintained and bare areas seeded.

Safety

- Porous pavement systems have the same safety considerations as conventional paving systems.
- OSHA health and safety guidelines should be followed for safe construction practices. Additional information on safety for construction sites is available from OSHA. Use the following link to research safety measures for excavation sites: http://www.osha.gov/pls/oshaweb/

Construction Details

Because of the proprietary nature of pervious surface systems, no construction details are provided.

C. Construction Specifications

Given that the construction of pervious surfaces incorporates techniques or steps which may be considered non-standard; it is RECOMMENDED that the construction specifications include the following format and information.

I. Temporary Erosion Control
   - Installation prior to site disturbance
   - Catch basin/inlet protection

II. Excavation, Backfill and Grading
   - Gravel filter specifications (if required)
   - Filter fabric specifications (if required)

III. Construction Sequence Scheduling
- ► Temporary construction access
- ► Location of silt fence installation to protect BMPs and downgradient receiving waters
- ► Construct pervious surface system
- ► Seeding and mulching disturbed areas
- ► Site stabilization
- ► Silt fence removal

IV. Construction Observation
- ► Adherence to construction documents
- ► Verification of physical site conditions
- ► Erosion control measures installed appropriately

D. Operation and Maintenance

Overview

Effective long-term performance of pervious surfaces can be ensured by completing a performance monitoring plan (RECOMMENDED), and a dedicated and routine maintenance schedule with clear guidelines and schedules (REQUIRED).

The monitoring plan should address the following items: inspection and efficiency assessment, water quality and quantity monitoring of runoff leaving the pervious surface, and physical damages.

Elements to be considered for the development of a maintenance plan are broken into the following categories: Construction Phase Maintenance Considerations; and Post-Construction Maintenance Considerations. In general terms, the most frequently cited maintenance concern for pervious surfaces is clogging caused by organic matter and fine silts.

Construction Phase Maintenance Considerations

Pervious surfaces that are expected to infiltrate stormwater are particularly vulnerable during the construction phase for two reasons. First, if the construction sequence is not followed correctly, construction sediment can clog the practice. In addition, construction with heavy equipment can result in compaction of the soil, which can then reduce the underlying soil's infiltration rate. For this reason, a careful construction sequence needs to be followed. Critical construction elements for pervious surfaces are as follows:

- ► ***Avoid excessive compaction***
  It is REQUIRED that in order to prevent soil compaction, the proposed pervious surface area be staked off and marked during construction to prevent heavy equipment and traffic from traveling over it and so that the practice area is not used as a construction staging area.
- ► ***Stabilize Vegetation Before and After Construction***
  Excessive sediment loadings can occur without the use of proper erosion and sediment control practices during the construction process. It is REQUIRED that upland drainage areas be properly stabilized with a thick layer of vegetation, particularly immediately following construction, to reduce sediment loads. If pervious surfaces are in-place during construction activities, it is REQUIRED that sediment and runoff be kept away from the area, such as with diversion berms and soil-stabilizing vegetation around the perimeter of the surface.
- ► ***Keep Pervious Surfaces "Off-line" until Construction Is Complete***
  It is REQUIRED that sediment and runoff be kept completely away from the pervious surfaces during construction. Thus, pervious surfaces should never serve as sediment control devices during site construction. It is HIGHLY RECOMMENDED that construction of pervious surfaces be suspended during snowmelt or rainfall, in order to prevent soil smearing, clumping, or compaction.

- ***Inspections***
  Inspections during construction are needed to ensure that the pervious surface is built in accordance with the approved design and standards and specifications. Detailed inspection checklists should be used that include sign-offs by qualified individuals at critical stages of construction to ensure that the contractor's interpretation of the plan is acceptable to the designer.

Post-construction Operation and Maintenance

A maintenance plan clarifying maintenance responsibility is REQUIRED. Effective long-term operation of pervious surfaces necessitates a dedicated and routine maintenance schedule with clear guidelines and schedules. Some important post-construction maintenance considerations are provided below. A more detailed checklist of maintenance activities and associated schedules is provided in Chapter 10.

- A legally binding and enforceable maintenance agreement should be executed between the practice owner and the City of Inver Grove Heights.
- Adequate access must be provided for all pervious surfaces for inspection, maintenance, and landscaping upkeep, including appropriate equipment and vehicles.

Construction and Maintenance Costs

Table 8.14 is a list of the general components used in construction of this practice. Utilizing Table 8.14 will allow designers to avoid over or under estimation of fixed costs.

Table 8.14 Pervious Surface Cost Components

Implementation Stage	Primary Cost Components	Basic Cost Estimate
Structural Components	Pervious Surface	($/square foot)
	Outflow components	($/structure)
	Stone aggregate storage layer	($/cubic yard)
	Underdrain (if used)	($/Linear Foot)
Annual Operation, Maintenance, and Inspection	Sweeping	Removal Cost ($/acre) x Area (acre) x Frequency (1x / 5yr)
	Vacuuming	Removal Cost ($/acre) x Area (acre) x Frequency (1x / 5yr)
	Inspection	Inspection Cost ($) x Inspection Frequency (6x / 1 yr)

Design Procedure

Because of the proprietary nature of pervious surfaces, a design procedure is not listed.

E. Additional Resources

Georgia Stormwater Management Manual. 2001. Atlanta Regional Commission.
http://www.georgiastormwater.com/

Minnesota Pollution Control Agency. The Minnesota Stormwater Manual. 2005.
http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html#manual

Vermont Stormwater Management Manual. 2002.
http://www.vtwaterquality.org/stormwater.htm.

Wisconsin DNR Site Evaluation for Stormwater Infiltration Conservation Practice Standard 1002. 2004.
http://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm#Post.

Wisconsin DNR Infiltration Basin Conservation Practice Standard 1003. 2004.
http://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm#Post.

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FILTRATION

Lino Lakes City Hall - Lino Lakes, MN

City of Woodbury, MN

Definition:
Structural stormwater controls that capture, temporarily store, and route stormwater runoff through a filter bed to improve water quality.

KEY CONSIDERATIONS

Design Criteria:

- Ensure adequate space for filtration system
- Some installations require 2-6 feet of head
- Removal potential of the key pollutant
- Parent material and potential for ground water contamination

Benefits:

- Good for highly impervious areas with low sediment/high pollutant load (e.g. urban land use and retrofit scenarios)
- High pollutant removal rates
- May be used in a variety of soil types
- Good for the treatment of hotspots because it can be isolated from ground water if contamination concerns exist

Limitations:

- Higher maintenance requirements
- Some installations (media filters) have higher construction costs
- Potential to cause odor problems
- Minimal treatment of soluble nutrients
- Potential for nitrification in media filters where anaerobic conditions exist

MANAGEMENT SUITABILITY

	Volume Control
X	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
	Wetland Bounce

MECHANISMS

X*	Infiltration *with appropriate soil & site conditions
X	Screening/ Filtration
	Temperature Control
	Settling
X	Evaporation
X*	Transpiration *if vegetated
X	Soil Adsorption
X	Biological/ Micro. Uptake

POLLUTION REMOVAL

85%	Total Suspended Solids
50%/35%	Nutrients - Total Phosphorus/ Total Nitrogen
50%	Metals - Cadmium, Copper, Lead, and Zinc
35%	Pathogens - Coliform, Streptococci, E. Coli
80%	Toxins - Chloride, Hydrocarbon, Pesticide

SITE FACTORS

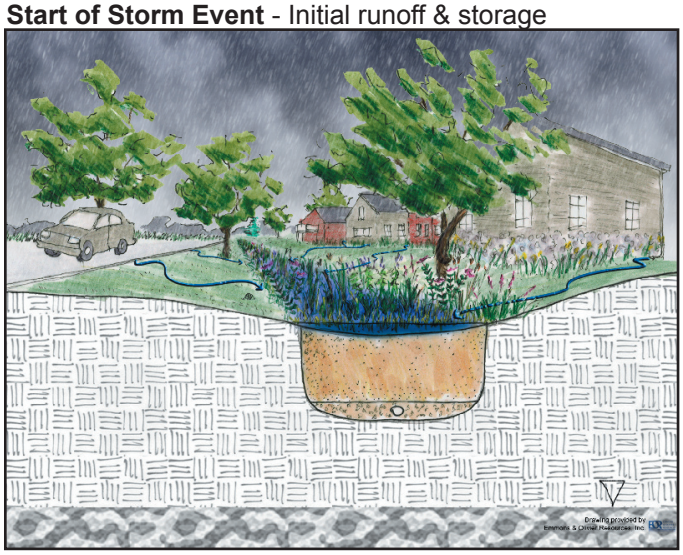
5 AC Max	Drainage Area
20%	Max. Site Slope
3'	Min. Depth to Bedrock
3'	Min. Depth to Seasonally High Water Table
A,B,C,D	NRCS Soil Type
Poor - Good	Freeze/ Thaw Suitability
Suitable	Potential Hotspot Runoff *requires impermeable liner

Description:
Filtration systems vary in their operation and applicability, but all can be described as structural BMPs that function mainly to enhance water quality by passing stormwater through a media. The media can be made of sand, peat, grass, soil, compost or vegetation and should be assigned on a case-by-case basis. Filters can be off-line systems or designed as pre-treatment before discharging to other stormwater features.

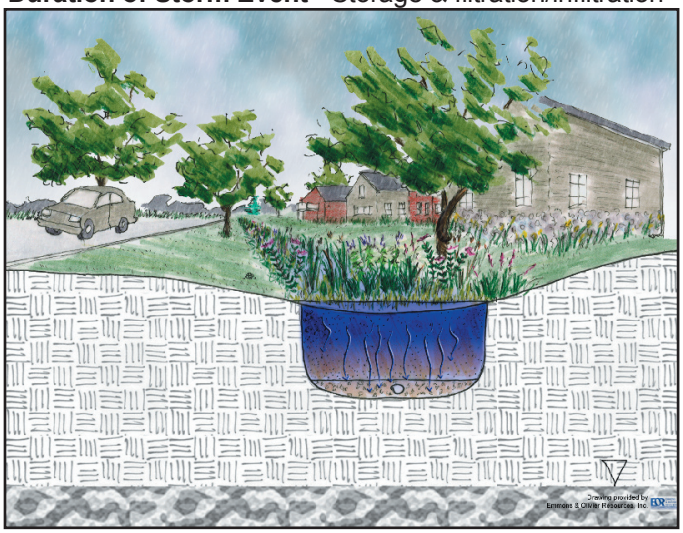
The two main categories of filtration systems include: media filters, and vegetated filters. Media filters can be located on the surface, underground, along the perimeter of an area, or in what is called a pocket design. Vegetated channels may be grass channels, dry or wet swales, submerged gravel wetlands, or filter strips.

STORM SEQUENCE

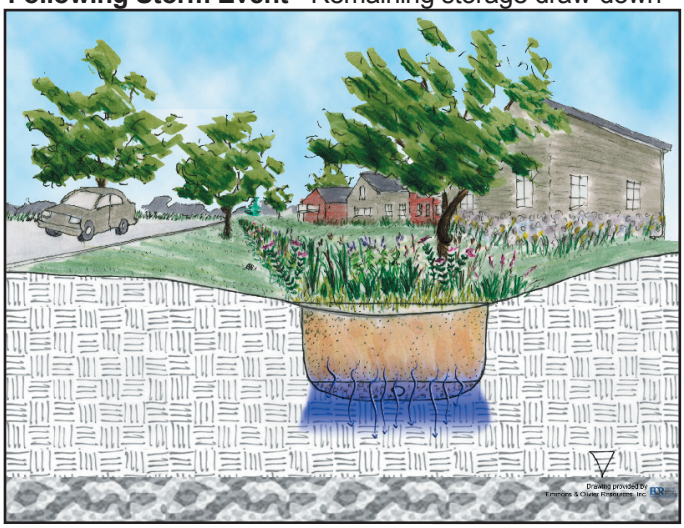
Start of Storm Event - Initial runoff & storage



Duration of Storm Event - Storage & filtration/infiltration



Following Storm Event - Remaining storage draw-down



Courtesy of Rice Creek Watershed District

A. Suitability

General

Filtering practices include media filters (surface, underground, perimeter), vegetative filters (filter strips, grass channels), and combination media/vegetative filters (dry swales). Media and media/vegetative filters operate similarly and provide comparable water quality capabilities as bioretention. Vegetative filters are generally more suitable as pretreatment practices, but in some situations can be used on a standalone basis.

Filtering practices have widespread applicability and are suitable for all land uses, as long as the contributing drainage areas are limited (e.g., typically less than 5 acres). Media filters are not as aesthetically appealing as bioretention, which makes them more appropriate for commercial or light industrial land uses or in locations that will not receive significant public exposure. Media filters are particularly well suited for sites with high percentages of impervious cover (e.g., > 50%). Media filters can be designed with an underdrain, which makes them a good option for treating potential stormwater hotspots (PSHs). They can also be installed underground, to prevent the consumption of valuable land space (often an important retrofit or redevelopment consideration). Vegetative filters can be incorporated into landscaped areas, providing dual functionality.

Function Within Stormwater Treatment Train

Media filtration systems are designed primarily as off-line systems for stormwater quality and typically are used in conjunction with another structural control. Vegetative filters, designed as grass channels or swales, may be the main form of conveyance between or out of BMPs, as well as providing treatment for stormwater runoff.

Permit Applicability

One of the goals of this manual is to facilitate an understanding of and compliance with the city of Inver Grove Heights' Volume Control Standard. This standard must be met on all new and re-development projects taking place in the northwest area.

Filtering devices generally may be used to meet the Inver Grove Heights pretreatment requirements. Stormwater filtering systems that incorporate infiltration may also reduce the 5-year 24-hour infiltration standard by the amount that the practice is able to store and infiltrate. Additional volume credit may be allowed (such as a swale that doesn't contain storage areas, but has a fast infiltration rate) but the amount of volume credit will need to be approved by the city engineer.

The following terms are thus used in the text to distinguish various levels of filtration practice design guidance:

REQUIRED:	Indicates design standards stipulated by the IGH PUD.
HIGHLY RECOMMENDED:	Indicates design guidance that is extremely beneficial or necessary for proper functioning of the practice, but is not specifically required by the City of Inver Grove Heights.
RECOMMENDED:	Indicates design guidance that is helpful for performance but not critical to the design.

Design Variants (Adapted from Georgia Stormwater Manual and Center for Watershed Protection)

As filtration becomes a more common tool in stormwater management, and as the number of design variants increases, so does the number of names for each of these variants. For example:

- Sand filters are also referred to as filtration basins, filter systems, first-flush filtration, or media filtration systems.
- Grass channels are also referred to as biofilters. (Seattle METRO, 1992 from CWP)
- Dry swales are also referred to as grassed or vegetated swales.

The following types of filtration systems can be used depending upon project scale and site conditions:

Media Filters

- ***Surface Sand Filter*** – For a surface sand filter, a flow splitter is used to divert runoff into an off-line sedimentation chamber. The chamber may be either wet or dry, and is used for pretreatment. Runoff is then distributed into the second chamber, which consists of a sand filter bed (~18") and temporary runoff storage above the bed. Pollutants are trapped or strained out at the surface of the filter bed. The filter bed surface may have a sand or grass cover. A series of perforated pipes located in a gravel bed collect the runoff passing through the filter bed, discharge it to the next downstream BMP. If underlying soils are permeable, and groundwater contamination unlikely, the bottom of the filter bed may have no lining, and the filtered runoff may be allowed to infiltrate.
- ***Underground Sand Filter*** – The underground sand filter was adapted for sites where space is at a premium. In this design, the sand filter is placed in a three chamber underground vault accessible by manholes or grate openings. The vault can be either on-line or off-line in the storm drain system. The first chamber is used for pretreatment and relies on a wet pool as well as temporary runoff storage. It is connected to the second sand filter chamber by an inverted elbow, which keeps the filter surface free from trash and oil. The filter bed is 18 inches in depth and may have a protective screen of gravel or permeable geotextile to limit clogging. During a storm, the water quality volume is temporarily stored in both the first and second chambers. Flows in excess of the filter's capacity are diverted through an overflow weir. Filtered runoff is collected, using perforated underdrains that extend into the third "overflow" chamber.
- ***Perimeter Sand Filter*** – The perimeter sand filter consists of two parallel trench-like chambers that are typically installed along the perimeter of a parking lot. Parking lot runoff enters the first chamber, which has a shallow permanent pool of water. The first trench provides pretreatment before the runoff spills into the second trench, which consists of a sand layer (12"-18"). During a storm event, runoff is temporarily ponded above the normal pool and sand layer, respectively. When both chambers fill up to capacity, excess parking lot runoff is routed to a bypass drop inlet. The remaining runoff is filtered through the sand, and collected by underdrains and delivered to a protected outflow point.

Vegetative Filters

- ***Grass Channels*** – Grass channels can be designed to meet a runoff velocity target for a water quality storm as well as the peak discharge from a 2-year design storm. Grass channels can be designed to pass larger storms and serve as conveyance tools. Pretreatment can be created by placing checkdams across the channel below pipe inflows, and at various other points along the channel. Grass channels do not provide adequate pollutant removal benefits to act as a stand-alone BMP.
- ***Dry Swales*** – In dry swales, additional volume can temporarily be retained by checkdams during each storm. Unlike the grass channel, the filter bed in the swale is 30 inches of prepared soil. Water is filtered through the sandy loam to underdrains and the swale is quickly dewatered. In the event that surface soils clog, the dry swale has a pea gravel window on the downstream side of each checkdam to route water to the underdrain. Dry swales are often preferred in residential areas because they prevent standing water.
- ***Wet Swales*** – Wet swales occur when the water table is located very close to the surface. This wet swale acts as a very long and linear shallow wetland treatment system. Like the dry swale, additional

stormwater volume is stored within a series of cells created by checkdams. Cells may be planted with emergent wetland plant species to improve pollutant removal.

- ***Filter Strips*** – Filter strips rely on the use of vegetation to slow runoff velocities and filter out sediment and other pollutants from urban stormwater. To be effective, however, filter strips require the presence of sheet flow across the entire strip. Once flow concentrates to form a channel, it effectively short-circuits the filter strip. In the most common design, runoff is directed from a parking lot into a long filtering system composed of a stone trench, a grass strip and a longer naturally vegetative strip. In addition, a stone drop can be located at the edge of the parking lot and the filter strip to prevent sediments from depositing at this critical entry point. The filter strip is typically an on-line practice, so it must be designed to withstand the full range of storm events without eroding. Filter strips do not provide adequate pollutant removal benefits to act as a stand-alone BMP.

Other Filters Not Approved For Inver Grove Heights

The following filters are not approved for use in Inver Grove Heights due to **high probability of failure** under cold climate conditions. They are included here for informational purposes only.

- ***Organic Filter*** – The organic filter functions in much the same way as the surface sand filter, but uses leaf compost or a peat/sand mixture as the filter media instead of sand (peat should not be used when the target pollutant for removal is a dissolved nutrient). The organic material enhances pollutant removal by providing adsorption of heavy metals. In an organic filter, runoff is diverted with a flow splitter into a pretreatment chamber, from which it passes into one or more filter cells. Each filter bed contains a layer of leaf compost or the peat/sand mixture, followed by a filter fabric and perforated pipe and gravel. Runoff filters through the organic media to the perforated pipe and ultimately to the outlet. The filter bed and subsoils can be separated by an impermeable polyliner to prevent movement into groundwater.
- ***Pocket Filter*** – Pocket sand filters are intended as an inexpensive utilization of sand filters where sediment loads do not warrant a sedimentation chamber and can suffice with a grass filter strip and a plunge pool. The filter bed is comprised of a shallow basin containing the sand filter medium. The filter surface is a layer of soil and a grass cover. In order to avoid clogging the filter has a pea gravel "window" which directs runoff into the sand and a cleanout and observation well. Typically the filtered runoff is allowed to exfiltrate to groundwater, although underdrains may be needed if the soils are not suitably permeable.
- ***Submerged Gravel Wetland*** – Submerged gravel filters consist of a series of cells that are filled with crushed rock or gravel. The standpipe from each cell is set at an elevation that keeps the rock or gravel submerged. Wetland plants are rooted in the media, where they can directly take up pollutants. The anaerobic conditions on the bottom of the filter can foster the de-nitrification process. Submerged gravel wetlands are not recommended for stormwater quality in cold climate conditions, although they have been used in Minnesota for effluent polishing of wastewater.

Retrofit Suitability

The use of filters as a retrofit practice primarily depends on existing infrastructure and the compatibility of existing storm drain inverts that need to connect to the filter underdrain outflow. In general, four to six feet of elevation above the existing collection system invert is needed for media filter retrofits (2-3 feet is needed for perimeter filters). Underground media filters are excellent for ultra-urban settings where space is at a premium.

Cold Climate Suitability

Various options for use of filtration are available for treating snowmelt runoff. Some of the installations are built below the frost line (trenches, sub-grade proprietary chambers) and do not need further adaptation for the cold. However, some special consideration is HIGHLY RECOMMENDED for surface systems.

The problem with filtration in cold weather is the ice that forms both over the top of the facility and within the soil interstices. To avoid these problems to the extent possible, it is HIGHLY RECOMMENDED that the facility be actively managed to keep it dry before it freezes in the late fall. This can be done by various methods, including limiting inflow, under-drainage, and surface disking.

Proprietary, sub-grade filtration systems provide an alternative to standard surface based systems. Essentially, these systems provide an insulated location for snowmelt to be stored and filtered. The insulating value of these systems adds to their appeal as low-land-consumption alternatives to other BMPs.

Water Quantity Treatment

Filters are not typically a primary practice for providing water quantity control. They are normally configured to safely pass large storm flows while still protecting the filter bed. Vegetative filters, in particular, can help reduce stormwater volume control standard for a site by providing volumetric losses from infiltration and evapo-transpiration. Generally, however, to meet site water quantity criteria, it is HIGHLY RECOMMENDED that another structural control be used in conjunction with a filter.

Water Quality Treatment

Filters are an excellent stormwater treatment practice with the primary pollutant removal mechanism being filtering and settling. Less significant processes can include evaporation, infiltration, transpiration, biological and microbiological uptake, and soil adsorption. Pollutant removal and effluent concentration data for select parameters are provided in Tables 8.15 and 8.16, respectively. While it is possible to design media filters to discharge a portion of the effluent to the groundwater, they are typically designed as enclosed systems (i.e., no “infiltration”). Vegetative filters, on the other hand, can readily be designed as an effective infiltration / recharge practice, particularly when parent soils have good permeability (> ~ 0.5 in/hr). Consult the Pretreatment section on page 71 for more guidance on how to use filters to meet pretreatment water quality and recharge criteria.

Table 8.15 Percent Removal of Key Pollutants by Practice Group

Practice	TSS [%]	Total Phosphorus [%]	Total Nitrogen [%]	Metals[1] [%]	Bacteria [%]	Hydro-carbons [%]
Filtering Practices[2]	85	60	35[1]	60	35	80

Notes
1. Based on fewer than five data points (i.e., independent monitoring studies)
2. Higher removal rates for dry swales.

Removals represent median values

Source: Winer, 2000

Table 8.16 Typical BMP Best Performance Effluent Concentrations					
Practice	**TSS**	**TP**	**TN**	**Cu[1]**	**Zn[1]**
Filtering Practices	14	0.2	1.1	8	60

Notes
1. Units for Zn and Cu are micrograms per liter
2. Values from ASCE bmp database and Winer 2000 (shaded values)

Source: Winer, 2000

Limitations

The following general limitations should be recognized when considering installation of a filtration practice:

- Nitrification of water in media filters may occur where aerobic conditions exist
- Offers limited water quantity control
- Potential to create odors

B. Major Design Elements

Physical Feasibility Initial Check

Before deciding to use a filtration device for stormwater management, it is helpful to consider several items that bear on the feasibility of using such a device at a given location. The following list of considerations will help in making an initial judgment as to whether or not a filtration device is the appropriate BMP for the site.

- ***Drainage Area*** – 5 acres maximum RECOMMENDED (0.5 to 2 acres is ideal). Surface sand filters can sometimes be sized for drainage areas up to 10 acres, but only with rigorous and committed maintenance schedules, among other design and O&M considerations.
- ***Site Topography and Slopes*** – It is RECOMMENDED that sloped areas immediately adjacent to practice be less than 20% but greater than 1%, to promote positive flow towards the practice.
- ***Soils*** – No restrictions for media filters with underdrain is needed.
- ***Depth to Water Table and Bedrock*** – No minimum separation distance is needed if filter is fully enclosed (i.e., no exfiltration). A separation distance of at least 3 feet is REQUIRED under the state CGP between the bottom elevation of vegetative filters and the elevation of the seasonally high water table (does not apply to wet swales).
- ***Site Location/Minimum Setbacks*** – A minimum setback of 50' between a stormwater pond and a water supply well is REQUIRED by the Minnesota Department of Health Rule 4725.4350. For purposes of this guidance, it is assumed that the definition of a stormwater pond includes a stormwater filtration system.

Conveyance

It is HIGHLY RECOMMENDED that a flow splitter or diversion structure be provided to divert the 5-year volume control standard **(VCS)** to media filters and allow larger flows to bypass the practice. Where a flow splitter is not used, it is HIGHLY RECOMMENDED that contributing drainage areas be limited to approximately 0.5 acres and an overflow be provided within the practice to pass part of the **VCS** to a stabilized watercourse or storm drain. It is HIGHLY RECOMMENDED that the flow splitter be designed such that 75% of the **VCS** can enter the treatment system prior to flow bypass occurring at the flow splitter. The overflow weir between the sedimentation and filtration chambers may be adjusted to be lower in elevation than the flow splitter weir to minimize bypass of the filter system prior to inflow filling the 75% **VCS** storage.

It is HIGHLY RECOMMENDED that media filters be equipped with a minimum 8" diameter underdrain in a 1' gravel bed. Increasing the diameter of the underdrain makes freezing less likely. The porous gravel bed prevents standing water in the system by promoting drainage. Gravel is also less susceptible to frost heaving than finer grained media. It is also HIGHLY RECOMMENDED that a permeable filter fabric be placed between the underdrain and gravel layer but not extend laterally from the pipe more than two feet on either side.

Pretreatment

Filtration is envisioned as a pretreatment device in the Northwest Area. If filtration becomes the primary device, the following shall be taken into consideration:

- Dry or wet pretreatment is REQUIRED prior to media filter treatment (pretreatment volume equivalent to at least 25% of the computed **VCS** is HIGHLY RECOMMENDED). The typical method is a sedimentation basin with a RECOMMENDED minimum length to width ratio of 2:1. The Camp-Hazen equation is used to compute the target surface area for media filters requiring full sedimentation for pretreatment (WSDE, 1992).

- The RECOMMENDED pretreatment for vegetative filters is a level spreader that allows coarse sediment to settle and evenly distributes flow across the full width of the filter.

- The RECOMMENDED pretreatment for media / vegetative filters such as dry swales is to install plunge pools where concentrated flows enter and to place level spreaders where lateral flows enter.

- Additional pretreatment measures include filter strips and street / parking lot sweeping. Street / parking lot sweeping may be considered pretreatment in the case of a parking lot island or other area where spatial limitations make structural pretreatment measures unfeasible.

- When using media filters to treat PSHs, particularly in sensitive watersheds, it is HIGHLY RECOMMENDED that additional practices be incorporated as partial treatment during the winter when the filter bed may be frozen.

Treatment

The following guidelines are applicable to the actual treatment area of a filtration facility:

- ***Space Required*** – Function of available head at site for surface filters. Underground filters have little or no space requirements except for access.
- ***Practice Slope*** – The surface slope of media filters should be level to promote even distribution of flow throughout practice. It is HIGHLY RECOMMENDED that vegetative filters have a maximum slopes of 5% and a minimum slope of 1%.
- ***Depth*** – The RECOMMENDED elevation difference at a site from the inflow to the outflow is 4-6 feet for most sand filters, and 2-3 feet for perimeter filters.
- ***Groundwater Protection*** – Exfiltration of untreated PSH runoff into groundwater is PROHIBITED. At confirmed hotspots, it is REQUIRED that filtered runoff be directed to the existing storm drain system or surface receiving waters.
- ***Aesthetics*** – Vegetative filters can be effectively integrated into the site planning process, and aesthetically designed as attractive green spaces. Media filters are less conducive to site aesthetics, but surface media filters can be designed with turf cover crops if desired.

Landscaping

It is REQUIRED that impervious area construction be completed and pervious areas established with dense and healthy vegetation (see Appendix B) prior to introduction of stormwater into a filtration practice.

Surface filters can have a grass cover to aid in pollutant adsorption. The grass should be capable of withstanding frequent periods of inundation and drought.

Safety

It is REQUIRED that underground media filters only be accessed by individuals with appropriate confined space entry training. No building structures should be constructed on top of underground filters.

It is HIGHLY RECOMMENDED that swale side slopes be set at 3:1 (h:v) or flatter.

It is HIGHLY RECOMMENDED that perimeter sand filter grates be sufficiently heavy that they cannot be removed easily.

Fencing may be desirable in surface sand filter designs with significant vertical walls for the sedimentation and/or filter chamber. Fencing can also protect the filter from vandalism and limit animal access.

If a BMP is located in an area greater than five feet deep, it is REQUIRED that OSHA health and safety guidelines be followed for safe construction practices. Additional information on safety for construction sites is available from OSHA. Use the following link to research safety measures for excavation sites:

http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10930

Construction Details

- Underground Sand Filter
- Perimeter Sand Filter
- Dry Swales
- Wet Swales
- Outlet structure with drawdown valve
- Diversion
- Emergency Overflow

C. Construction Specifications

Given that the construction of infiltration practices incorporates techniques or steps which may be considered non-standard, it is RECOMMENDED that the construction specifications include the following format and information.

I. Temporary Erosion Control
   - Installation prior to site disturbance
   - Catch basin/inlet protection
   - Use of BMP as temporary sedimentation basin

II. Excavation, Backfill and Grading
   - Timing of grading of filtration practices (relative to total site development)
   - Use of low-impact, earth moving equipment
   - Restoration in the event of sediment accumulation during construction of practice
   - Gravel backfill specifications
   - Gravel filter specifications
   - Filter fabric specifications
   - Observation well specifications (if necessary)

III. Native Plants, Planting and Transplanting (Plant Material Selection in Appendix B of the Manual)
- Site preparation of planting areas
- Timing of native seeding and native planting
- Weed control
- Watering of plant material

IV. Construction Sequence Scheduling
- Temporary construction access
- Location of silt fence installation to protect BMPs and downgradient receiving waters
- Removal and storage of excavated material
- Installation of underground utilities
- Rough grading
- Seeding and mulching disturbed areas
- Road construction
- Final grading
- Site stabilization
- Installation of semi-permanent and permanent erosion control measures
- Silt fence removal

V. Construction Observation
- Adherence to construction documents
- Verification of physical site conditions
- Erosion control measures installed appropriately

Table 8.17 Sand Material Specifications

Parameter	Specification	Size	Notes
Sand	clean AASHTO M-6 or ASTM C-33 concrete sand	0.02” to 0.04”	Sand substitutions such as Diabase and Graystone #10 are not acceptable. No calcium carbonated or dolomitic sand substitutions are acceptable. Rock dust cannot be substituted for sand.
Underdrain Gravel	AASHTO M-43	1.5” to 3.5”	
Geotextile Fabric (if required)	ASTM D-4833 (puncture strength - 125 lb.) ASTM D-1117 (Mullen Burst Strength - 400 psi) ASTM D-4632 (Tensile Strength - 300 lb.)	0.08” thick equivalent opening size of #80 sieve	Must maintain 125 gpm per sq. ft. flow rate. Note: a 4” pea gravel layer may be substituted for geotextiles meant to separate sand filter layers.
Impermeable Liner (if required)	ASTM D-4833 (thickness) ASTM D-412 (tensile strength 1,100 lb., elongation 200%) ASTM D-624 (Tear resistance - 150 lb./in) ASTM D-471 (water adsorption: +8 to -2% mass)	30 mil thickness	Liner to be ultraviolet resistant. A geotextile fabric should be used to protect the liner from puncture.
Underdrain Piping	ASTM D-1785 or AASHTO M-278	8” rigid schedule 40 PVC	3/8” perf. @ 6” on center, 4 holes per row; minimum of 3” of gravel over pipes; not necessary underneath pipes
Concrete (Cast-in-place)	See local Standards and Specs. f’c = 3,500 psi, normal weight, air-entrained; re-enforcing to meet ASTM 615-60	n/a	on-site testing of poured-in-place concrete required: 28 day strength and slump test; all concrete design (cast-in-place or pre-cast) *not using previously approved State or local standards* requires design drawings sealed and approved by a licensed professional structural engineer.
Concrete (pre-cast)	per pre-cast manufacturer	n/a	SEE NOTE ABOVE
non-rebar steel	ASTM A-36	n/a	structural steel to be hot-dipped galvanized ASTM A-123

Source: Adapted from Vermont Stormwater Manual prepared by CWP

Table 8.18. Open Vegetated Swale and Filter Strip Materials Specifications			
Parameter	**Specification**	**Size**	**Notes**
Dry swale soil	USCS; ML, SM, SC	n/a	soil with a higher percent organic content is preferred
Dry Swale sand	ASTM C-33 fine aggregate concrete sand	0.02” to 0.04”	
Check Dam (pressure treated)	AWPA Standard C6	6” by 6” or 8” by 8”	*Do not* coat with creosote; embed at least 3’ into side slopes
Check Dam (natural wood)	Black Locust, Red Mulberry, Cedars, Catalpa, White Oak, Chestnut Oak, Black Walnut	6” to 12” diameter; notch as necessary	*Do not* use the following, as these species have a predisposition towards rot: Ash, Beech, Birch, Elm, Hackberry, Hemlock, Hickories, Maples, Red and Black Oak, Pines, Poplar, Spruce, Sweetgum, Willow
Filter Strip sand/ gravel pervious berm	sand: per dry swale sand gravel; AASHTO M-43	sand: 0.02” to 0.04” gravel: 1/2” to 1”	Mix with approximately 25% loam soil to support grass cover crop; see Bioretention planting soil notes for more detail.
Pea gravel diaphragm and curtain drain	ASTM D 448	varies (No. 6) or (1/8” to 3/8”)	Use clean bank-run gravel
Underdrain gravel	AASHTO M-43	1.5” to 3.5”	
Underdrain	ASTM D-1785 or AASHTO M-278	6” rigid Schedule 40 PVC	3/8” perf. @ 6” o.c.; 4 holes per row
Geotextile	See local Standards and Specs	n/a	
Rip rap	per local criteria	size per requirements based on 10-year design flows	

Source: Adapted from Vermont Stormwater Manual prepared by CWP

D. Operation and Maintenance

Overview

The most frequently cited maintenance concern for filters is surface and underdrain clogging caused by organic matter, fine silts, hydrocarbons, and algal matter. Common operational problems include:

- standing water
- clogged filter surface
- clogged, inlet, outlet or underdrains

Design Phase Maintenance Considerations

Implicit in the design guidance in the previous sections is the fact that many design elements of filtering systems can minimize the maintenance burden and maintain pollutant removal efficiency. Key examples include: limiting drainage area, providing easy site access (REQUIRED), and providing adequate pretreatment (REQUIRED).

Construction Phase Maintenance

Proper construction methods and sequencing play a significant role in reducing problems with operation and maintenance (O&M). In particular, with filter construction the most important action for preventing operation and maintenance difficulties is to ensure that the contributing drainage area has been fully stabilized prior to bringing the practice on line (this is a REQUIRED practice).

Inspections during construction are needed to ensure the filter practice is built in accordance with the approved design and standards and specifications. Detailed inspection checklists should be used that include sign-offs by qualified individuals at critical stages of construction, to verify the contractor's interpretation of the plan is acceptable with the designer. An example construction phase inspection checklist is provided in Appendix D.

Post-construction Operation and Maintenance

A maintenance plan clarifying maintenance responsibility is REQUIRED. Effective long-term operation of filtration practices necessitates a dedicated and routine maintenance schedule with clear guidelines and schedules. Some important post-construction considerations are provided below along with RECOMMENDED maintenance standards. A more detailed checklist of maintenance activities and associated schedules is provided in Appendix D.

- A site specific O&M plan that includes the following considerations should be prepared by the designer prior to putting the stormwater filtration practice into operation:
  - Operating instructions for drawdown valves, gates and removable weirs (surface filters only)
  - Vegetation maintenance schedule
  - Inspection checklists
  - Routine maintenance checklists

- A legally binding and enforceable maintenance agreement should be executed between the facility owner and the local review authority to ensure the following:
  - Sediment should be cleaned out of the sedimentation chamber when it accumulates to a depth of more than six inches. The sediment chamber outlet devices should be cleaned/repaired when drawdown times exceed 72 hours (48 hours if its being used to meet MPCA requirements). Trash and debris should be removed as necessary.
  - Silt/sediment should be removed from the filter bed when the accumulation exceeds one inch. When the filtering capacity of the filter diminishes substantially (i.e., when water ponds on the surface of the filter bed for more than 72 hours), the top few inches of discolored material should be removed and replaced with fresh material. The removed sediments should be disposed in an acceptable manner (i.e., landfill).

- Media filters that have a grass cover should be mowed as needed during the growing season to maintain maximum grass heights less than 12 inches.

Table 8.19 Recommended Maintenance Activities for Media Filters	
Activity	**Schedule**
► If filter bed is clogged or partially clogged, manual manipulation of the surface layer of sand may be required. Remove the top few inches of media, roto-till or otherwise cultivate the surface, and replace media with like material meeting the design specifications. ► Replace any filter fabric that has become clogged.	As needed
► Ensure that contributing area, facility, inlets and outlets are clear of debris. ► Ensure that the contributing area is stabilized and mowed, with clippings removed. ► Remove trash and debris. ► Check to ensure that the filter surface is not clogging (also check after storms greater than about 1”). ► Ensure that activities in the drainage area minimize oil/grease and sediment entry to the system. ► If permanent water level is present in pretreatment chamber (e.g., perimeter sand filter), ensure that the chamber does not leak, and normal pool level is retained.	Monthly
► Check to see that the filter bed is clean of sediment and the sediment chamber is not more than 6 inches of sediment. Remove sediment as necessary. ► Make sure that there is no evidence of deterioration, spalling or cracking of concrete. ► Inspect grates (perimeter sand filter). ► Inspect inlets, outlets and overflow spillway to ensure good condition and no evidence of erosion. ► Repair or replace any damaged structural parts. ► Stabilize any eroded areas. ► Ensure that flow is not bypassing the facility. ► Ensure that no noticeable odors are detected outside the facility.	Annually
► Remove and replace the top 2-5 inches of media every 3 to 5 years for low sediment applications, more often for areas of high sediment yield or high oil and grease.	3 to 5 years

Source: WMI, 1997, Pitt, 1997

Construction and Maintenance Costs

Table 8.20 is a list of the general components used in construction of this practice. Utilizing Table 8.20 will allow designers to avoid over or under estimation of fixed costs.

Table 8.20 Filtration Cost Components

Implementation Stage	Primary Cost Components	Basic Cost Estimate	Other Considerations
Site Preparation	Tree & plant protection	Protection Cost ($/acre) x Affected Area (acre)	Removal of existing structures, topsoil removal and stockpiling
	Topsoil salvage	Salvage cost ($/acre) x Affected Area (acre)	
	Clearing & grubbing	Clearing Cost ($/acre) x Affected Area (acre)	
Site Formation	Excavation / grading	X-ft Depth Excavation Cost ($/acre) x Area (acre)	Soil & rock fill material, tunneling
	Hauling material offsite	Excavation Cost x (% of Material to be hauled away)	
Structural Components	Underdrains	Underdrain cost ($/lineal foot) x length of device	Pipes, catchbasins, manholes, valves, vaults
	Vault structure (for media filters)	($/structure)	
	Media (for media filters)	Media cost ($/cubic yard) x filter volume (cubic yard)	
	Inlet structure (for vegetative filters	($/structure)	
	Outlet structure (for vegetative filters)	($/structure)	
Site Restoration	Filter strip	Sod cost ($/square foot) x filter strip area	Tree protection, soil amendments, seed bed preparation, trails
	Soil preparation	Topsoil or amendment cost ($/acre) x Area (acre)	
	Seeding	Seeding Cost ($/acre) x Seeded Area (acre)	
	Planting / transplanting	Planting Cost ($/acre) x Planted Area (acre)	
Annual Operation, Maintenance, and Inspection	Debris removal	Removal Cost ($/acre) x Area (acre) x Frequency (2x / 1yr)	Vegetation maintenance, cleaning of structures
	Sediment removal	Removal Cost ($/acre) x Area (acre) x Frequency (1x / 5yr)	
	Gate / valve operation	Operation Cost ($) x Operation Frequency (2x / 1 yr)	
	Inspection	Inspection Cost ($) x Inspection Frequency (6x / 1 yr)	
	Mowing (for some vegetative filters)	Mowing Cost ($) x Mowing Frequency (4x / 1 yr)	

Designers are encouraged to use the cost worksheet included in Appendix F to estimate their BMP construction cost.

Design Procedure: Media Filters

The following steps outline a recommended design procedure for media filters in compliance with the Inver Grove Heights stormwater permit. Design recommendations beyond those specifically required by the permit are also included and marked accordingly.

Design Steps

Step 1. Make a preliminary judgment as to whether site conditions are appropriate for the use of a surface or perimeter sand filter, and identify the function of the filter in the overall treatment system

A. Consider basic issues for initial suitability screening

- ► Site drainage area
- ► Site topography and slopes
- ► Regional or local depth to groundwater and bedrock
- ► Site Location/Minimum setbacks

B. Determine how the media filter will fit into the overall stormwater treatment system

- ► Decide whether the filter is the only BMP to be employed, or if are there other BMPs addressing some of the treatment requirements.
- ► Decide where on the site the media filter is most likely to be located.

Step 2. Confirm design criteria and applicability.

A. Check with Inver Grove Heights, WMOs, and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.
B. Determine whether the media filter must comply with the MPCA construction general permit.

Step 3. Compute 5-year volume control standard and permanent pool volume.

Calculate the treatment volume per the standard (VCS).

Details on the Stormwater Sizing Criteria are found in Chapter 7.

Step 4. Select design variant based on Physical Suitability Evaluation

Once the Physical Suitability Evaluation is complete, apply the Better Site Design principles in sizing and locating the filtration practice(s) on the development site. Given the drainage area, select the appropriate filtration practice for the first iteration of the design process.

Note: Information collected during the Physical Suitability Evaluation (see Step 2) should be used to explore the potential for multiple filtration practices versus relying on a single facility. The use of smaller filtration practices dispersed throughout development is usually more sustainable than a single regional facility that is more likely to have maintenance problems (Source: Wisconsin Department of Natural Resources Conservation Practice Standards 2004).

Step 5. Size flow diversion structure, if needed

A flow regulator (or flow splitter diversion structure) should be supplied to divert the **VCS** to the sand filter facility.

Size low flow orifice, weir, or other device to pass $\mathbf{Q_{wq}}$.

Step 6. Size filtration basin chamber

The filter area is sized using the following equation (based on Darcy's Law):

$$Af = (VCS)\ (df)\ /\ [(k)\ (hf + df)\ (tf)]$$

Where:

Af = surface area of filter bed (ft^2)
VCS = **Volume Control Standard**
df = filter bed depth (typically 18 inches, no more than 24 inches)
k = coefficient of permeability of filter media (ft/day) (use 3.5 ft/day for sand)
hf = average height of water above filter bed (ft) (Typically 1/2 **hmax**, where **hmax** is the maximum head on the filter media and is typically ≤6 feet)
tf = design filter bed drain time (days) (3 days or 72 hours is required maximum)

Set preliminary dimensions of filtration basin chamber. The following guidelines are HIGHLY RECOMMENDED:

- The filter media should consist of an 18-inch layer of clean washed medium sand (meeting ASTM C-33 concrete sand) on top of the underdrain system.
- For surface sand filters, three inches of topsoil are placed over the sand bed. Permeable filter fabric is placed both above and below the sand bed to prevent clogging of the sand filter and the underdrain system.
- The filter bed is equipped with an 8-inch perforated PVC pipe (AASHTO M 252) underdrain in a gravel layer. The underdrain must have a minimum slope of 1%. Holes should be 3/8-inch diameter and spaced approximately 6 inches on center. Gravel should be clean washed aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches with a void space of about 40%. Aggregate contaminated with soil shall not be used.
- Underground sand beds should be protected from trash accumulation by a wide mesh geotextile screen to be placed on the surface of the sand bed. The screen is to be rolled up, removed, cleaned and re-installed during maintenance operations.

Step 7. Size sedimentation chamber

Sedimentation chamber size is dictated by volume requirements, maximum ponding depth, and the particle settling ability. It is HIGHLY RECOMMENDED that the sedimentation chamber be sized to at least 25% of the computed **VCS** for surface sand filters and 50% for perimeter sand filters and have a length-to-width ratio of 2:1. It is REQUIRED that the depth of settling basins be in the range of 3' to 10' ($\mathbf{D_{max}}$), although site-specific requirements may apply. The Camp-Hazen equation is used to compute the surface area based on particle settling:

$$As = -\ (Qo/w) * Ln\ (1-E)$$

Where:

As = sedimentation basin surface area (ft^2)
Qo = rate of outflow = the **VCS** over a 24-hour period
w = particle settling velocity (ft/sec)
E = trap efficiency

Assuming:

- 90% sediment trap efficiency (0.9)
- particle settling velocity (ft/sec) = 0.0004 ft/sec for imperviousness <75%
- particle settling velocity (ft/sec) = 0.0033 ft/sec for imperviousness ≥75%
- average of 24 hour holding period

Then the equation reduces to:

As = (0.066) (VCS) ft2 for I < 75%

Or

As = (0.0081) (VCS) ft2 for I ≥ 75%

Use the following charts to set the preliminary surface area of settling chamber. Select the type of filter, imperviousness of the drainage area, and maximum ponding depth,

Sand Filter		Maximum Ponding Depth (feet)	
		<4	4 to 10
Imperviousness	≥75%	(0.25*VCS)/Dmax	(0.25*VCS)/Dmax
	<75%	(0.25*VCS)/Dmax	0.066*VCS

Perimeter Sand Filter		Maximum Ponding Depth (feet)	
		<7.5	8 to 10
Imperviousness	≥75%	(0.5*VCS)/Dmax	(0.5*VCS)/Dmax
	<75%	(0.5*VCS)/Dmax	0.066*VCS

Step 8. Compute V_{min} (minimum volume that can be stored within the filtration chamber)

$$V_{min} = 0.75 * VCS$$

Step 9. Compute storage volumes within entire facility and sedimentation chamber orifice size

***Surface sand filter*:**

$$V_{min} = 0.75\ VCS = Vs + Vf + Vf_{temp}$$

(a) Compute **Vf** = water volume within filter bed/gravel/pipe = $Af * d_f * n$
Where: **n** = porosity = 0.4 for most applications

(b) Compute Vf_{temp} = temporary storage volume above the filter bed = $2 * hf * Af$

(c) Compute **Vs** = volume within sediment chamber = $V_{min} - Vf - Vf_{temp}$

(d) Compute **hs** = height in sedimentation chamber = **Vs/As**

(e) Ensure **hs** and **hf** fit available head and other dimensions still fit – change as necessary in design

iterations until all site dimensions fit.

(f) Size orifice from sediment chamber to filter chamber to release **Vs** within 24-hours at average release rate with 0.5 **hs** as average head.

(g) Design outlet structure with perforations allowing for a safety factor of 10.

Perimeter sand filter:

(a) Compute **Vf** = water volume within filter bed/gravel/pipe = **Af** * **df** * **n**
Where: **n** = porosity = 0.4 for most applications

(b) Compute **Vw** = wet pool storage volume **As** * 2 feet minimum

(c) Compute $\mathbf{Vf}_{temp}$= temporary storage volume = $\mathbf{V}_{min}$ – (**Vf** + **Vw**)

(d) Compute = $\mathbf{h}_{temp}$ = temporary storage height = $\mathbf{Vf}_{temp}$ / (**Af** + **As**)

(e) Ensure $\mathbf{h}_{temp} \geq \mathbf{2} * \mathbf{hf}$, otherwise decrease **hf** and re-compute. Ensure dimensions fit available head and area – change as necessary in design iterations until all site dimensions fit.

(f) Size distribution slots from sediment chamber to filter chamber.

<u>Step 10. Design inlets, pretreatment facilities, underdrain system, and outlet structures</u>

(a) Pretreatment of runoff in a sand filter system is provided by the sedimentation chamber. Inlets to surface sand filters are to be provided with energy dissipaters. Exit velocities from the sedimentation chamber must be nonerosive.

(b) Outlet pipe is to be provided from the underdrain system to the facility discharge. Due to the slow rate of filtration, outlet protection is generally unnecessary (except for emergency overflows and spillways).

(c) An emergency or bypass spillway must be included in the surface sand filter to safely pass flows that exceed the design storm flows. The spillway prevents filter water levels from overtopping the embankment and causing structural damage. The emergency spillway should be located so that downstream buildings and structures will not be impacted by spillway discharges.

(d) Inlets to surface sand filters are to be provided with energy dissipaters. Exit velocities from the sedimentation chamber must be nonerosive.

The allowable materials for sand filter construction are detailed in Table 8.17.

<u>Step 11. Compute overflow weir sizes</u>

Surface sand filter:

(a) Plan inlet protection for overflow from sedimentation chamber.

(b) Size overflow weir at elevation in filtration chamber above perforated stand pipe to handle surcharge of flow through filter system from 10-year storm.

Perimeter sand filter:

Size overflow weir at end of sedimentation chamber to handle excess inflow, set at VCS elevation.

Step 13. Check volume, peak discharge rates and period of inundation against State, local and Watershed Management Organization requirements (Note: Steps are iterative)

Follow the design procedures identified in chapter 7, Stormwater System Sizing, to determine the volume control standard.

Model the proposed development scenario using a surface water model appropriate for the hydrologic and hydraulic design considerations specific to the site. This includes defining the parameters of the filtration practice defined above: pond elevation and area (defines the pond volume), filtration rate and method of application (effective filtration area), and outlet structure and/or flow diversion information. The results of this analysis can be used to determine whether or not the proposed design meets the applicable requirements. If not, the design will have to be re-evaluated.

Period of Inundation

Filtration practices shall discharge through the soil or filter media in 72 hours or less. Additional flows that cannot be infiltrated or filtered in 72 hours should be routed to bypass the system through a stabilized discharge point. This criterion was established to provide the following: wet-dry cycling between rainfall events; unsuitable mosquito breeding habitat; suitable habitat for vegetation; aerobic conditions; and storage for back-to-back precipitation events.

The period of inundation is defined as the time from the high water level in the practice to 3 to 6 inches above the invert of the outlet structure or drain tile or bottom of the facility. It is assumed that this range is less than 1/5 the bounce in the filtration practice.

Design Procedure: Vegetative Filters (Adapted from the Georgia Stormwater Management Manual)

Design Steps

Step 1. Make a preliminary judgment as to whether site conditions are appropriate for the use of a vegetative filter, and identify the function of the filter in the overall treatment system

A. Consider basic issues for initial suitability screening

- ► Site drainage area
- ► Site topography and slopes
- ► Regional or local depth to groundwater and bedrock
  - *Dry Swale:* Bottom of facility to be above the seasonably high water table.
  - *Wet Swale:* The seasonally high water table may inundate the swale; but not above the design bottom of the channel
- ► Site Location/Minimum setbacks

B. Determine how the vegetative filter will fit into the overall stormwater treatment system

- ► Decide whether the filter is the only BMP to be employed, or if are there other BMPs addressing some of the treatment requirements.
- ► Decide where on the site the vegetative filter is most likely to be located.

Step 2. Confirm design criteria and applicability.

A. Check with Inver Grove Heights, WMOs, and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.
B. Determine whether the vegetative filter must comply with the MPCA Permit.

Step 3. Compute volume control standard

Details on the Stormwater Sizing Criteria are found in Chapter 7.

Step 4. Select design variant based on physical suitability evaluation

Once the physical suitability evaluation is complete, it is HIGHLY RECOMMENDED that the Better Site Design principles be applied in sizing and locating the filtration practice(s) on the development site. Given the drainage area, select the appropriate filtration practice for the first iteration of the design process.

Note: Information collected during the physical suitability evaluation (see Step 1) should be used to explore the potential for multiple filtration practices versus relying on a single facility. The use of smaller filtration practices dispersed around a development is usually more sustainable that a single regional facility that is more likely to have maintenance problems (Source: Wisconsin Department of Natural Resources Conservation Practice Standards 2004

Step 5. Determine pretreatment method

Pretreatment

Pretreatment for vegetative filters is REQUIRED. It should consist of a level spreader that allows coarse sediment to settle and evenly distributes flow across the full width of the filter. Pretreatment should be provided with plunge pools where concentrated flows enter and with level spreaders where lateral flows enter.

Additional pretreatment measures include filter strips and street/parking lot sweeping. Street/parking lot sweeping may be considered pretreatment in the case of a parking lot island or other area where spatial limitations make structural pretreatment measures unfeasible.

Step 6. Preliminary design

Wet and Dry Swales:

a. Size bottom width, depth, length, and slope necessary to store **VCS** with less than 18 inches of ponding at the downstream end.

b. Slope cannot exceed 4% (1 to 2% recommended)

c. Bottom width should range from 2 to 8 feet

d. Ensure that side slopes are no greater than 3:1 (4:1 recommended)

The peak velocity for the 2-year storm must be nonerosive for the soil and vegetative cover provided.

The channel and underdrain excavation should be limited to the width and depth specified in the design. The bottom of the excavated trench shall not be loaded in a way that causes soil compaction, and scarified prior to placement of gravel and permeable soil. The sides of the channel shall be trimmed of all large roots. The sidewalls shall be uniform with no voids and scarified prior to backfilling.

Step 7. Compute number of check dams (swales) or berms (filter strip)

Wet and Dry Swales: Checkdams

If checkdams are used a reduction in VCS may be realized.

Channel slopes between 1% and 2% are recommended unless topography necessitates a steeper slope, in which case 6- to 12-inch drop structures can be placed to limit the energy slope to within the recommended 1 to 2% range. Energy dissipation will be required below the drops. Spacing between the drops should not be closer than 50 feet. Depth of the **VCS** at the downstream end should not exceed 18 inches.

Step 8. Calculate draw-down time

Dry swale:

The bed of the dry swale consists of a permeable soil layer of at least 30 inches in depth, above an 8-inch diameter perforated PVC pipe (AASHTO M 252) longitudinal underdrain in a 12-inch gravel layer. The soil media should have an infiltration rate of at least 0.5 feet per day (fpd) with a maximum of 1.5 fpd and contain a high level of organic material to facilitate pollutant removal. A permeable filter fabric is placed between the gravel layer and the overlying soil.

Step 9. Check 2-year and 10-year velocity erosion potential and freeboard

Check for erosive velocities and modify design as appropriate based on soils. Provide 6 inches of freeboard.

Step 10. Design low flow control at downstream headwalls and checkdams
Design control to pass **VCS** in 6 hours.

Step 11. Design inlets, sediment forebay(s), and underdrain system (dry swale)

Inlets to swales must be provided with energy dissipaters such as riprap or geotextile reinforcement. Pretreatment of runoff in both a dry and wet swale system is typically provided by a sediment forebay located at the inlet. Enhanced swale systems that receive direct concentrated runoff may have a 6-inch drop to a pea gravel diaphragm flow spreader at the upstream end of the control. A pea gravel diaphragm and gentle side slopes should be provided along the top of channels to provide pretreatment for lateral sheet flows.

The underdrain system should discharge to the storm drainage infrastructure or a stable outfall. For a wet swale, do not use an underdrain system.

Step 12. Check volume, peak discharge rates and period of inundation against State, local and Watershed Management Organization requirements (Note: Steps are iterative)
Model the proposed development scenario using a surface water model appropriate for the hydrologic and hydraulic design considerations specific to the site. This includes defining the parameters of the filtration practice defined above: pond elevation and area (defines the pond volume), filtration rate and method of application (effective filtration area), and outlet structure and/or flow diversion information. The results of this analysis can be used to determine whether or not the proposed design meets the applicable requirements. If not, the design will have to be re-evaluated.

Period of Inundation

Filtration practices shall discharge through the soil or filter media in 72 hours or less. Additional flows that cannot be infiltrated or filtered in 72 hours should be routed to bypass the system through a stabilized

discharge point. This criterion was established to provide the following: wet-dry cycling between rainfall events; unsuitable mosquito breeding habitat; suitable habitat for vegetation; aerobic conditions; and storage for back-to-back precipitation events.

The period of inundation is defined as the time from the high water level in the practice to 3 to 6 inches above the invert of the outlet structure or drain tile or bottom of the facility. It is assumed that this range is less than 1/5 the bounce in the filtration practice.

Step 13. Prepare Vegetation and Landscaping Plan

A landscaping plan for a dry or wet swale should be prepared to indicate how the enhanced swale system will be stabilized and established with vegetation. The recommended construction materials for open channels and filter strips are detailed in Table 8.18. Further information on plant selection and use occurs in Appendix B of the manual.

Landscape design should specify proper grass species and wetland plants based on specific site, soils and hydric conditions present along the channel.

E. References

Design Hydrology and Sedimentology for Small Catchments. 1994. Haan, C.T., Barfield, B.J., Hayes, J.C.

Design of Stormwater Filtering Systems. 1996. Center for Watershed Protection.

Georgia Stormwater Management Manual. 2001. Atlanta Regional Commission.

Metropolitan Council. 2001. *Minnesota Urban Small Sites BMP Manual, Stormwater Best Management Practice for Cold Climates*. St. Paul, MN.

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BIORETENTION

Raingarden in a commercial development - Stillwater, MN

Definition:
Bioretention is a terrestrial-based (upland as opposed to wetland), water quality and water quantity control process. Bioretention employs a simplistic, site integrated design that provides opportunity for runoff infiltration, filtration, storage and water uptake by vegetation.

KEY CONSIDERATIONS

Design Criteria:

- Infiltration requires suitable soils.
- Minimum 10' setback and located down grade from home foundations.
- Best applied to drainage areas with relatively flat slopes (5%).

Benefits:

- Can be very effective for removing fine sediment, trace metals, nutrients, bacteria and organics (Davis *et al*. 1998).
- Provides many additional environmental (*habitat, improves air quality, urban micro-climates*), social (*creates a unique sense of place*) and economic benefits (*reduces development and maintenance cost, greater lot yield, increases property values*).
- Well suited for high impervious areas.
- Reduces runoff volume.
- Flexible design, affording many opportunities for creativity.

Limitations:

- Susceptible to clogging by sediment; therefore maintenance and pre-treatment is necessary to maintain effectiveness.
- Not effective for large drainage areas (use multiple structures, closer to source of runoff).
- Space consumption (5%-10% of drainage area).

MANAGEMENT SUITABILITY

X	Volume Control
X	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
X	Wetland Bounce

MECHANISMS

X*	Infiltration *with appropriate soils & site conditions
X	Filtration
X	Temperature Control
X	Settling
	Evaporation
X	Transpiration
X	Soil Adsorption
X	Biological/ Micro. Uptake

POLLUTION REMOVAL

85%	Total Suspended Solids
65%/ 50%	Nutrients - Total Phosphorus/ Total Nitrogen
95%	Metals - Cadmium, Copper, Lead, and Zinc
35%*	Pathogens - Coliform, Streptococci, E. Coli *less than 5 independent studies
80%*	Toxins - Chloride, Hydrocarbon, Pesticide *less than 5 independent studies

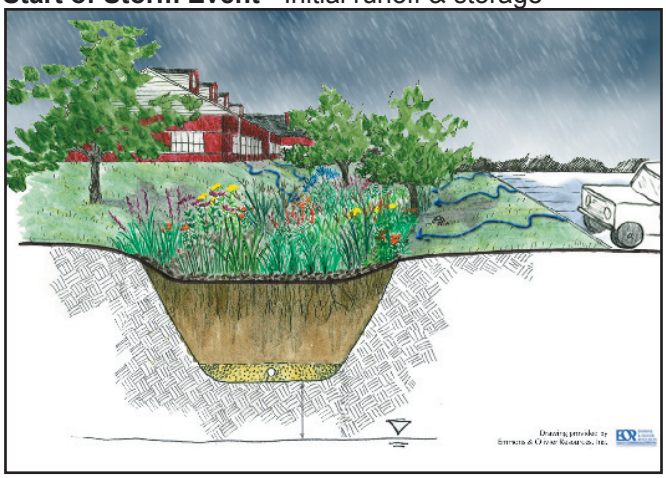
Note: Average pollutant removal expected when sizing based on MPCA criteria. Values apply to treated runoff only.

SITE FACTORS

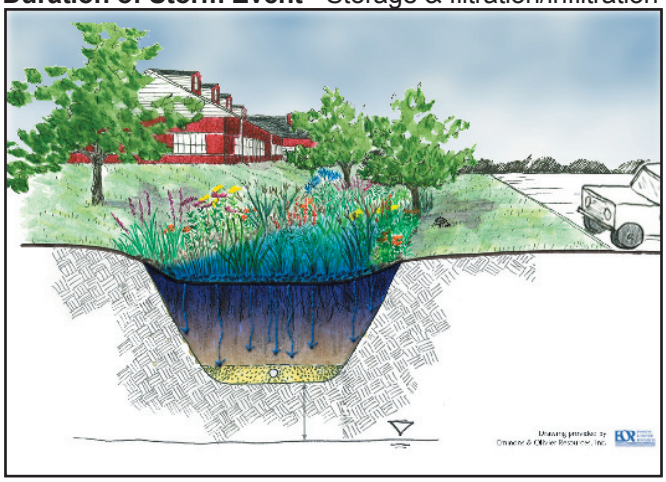
2 AC Max; 1 AC Max Impervious	Drainage Area For Filtration Design (Per Practice)
2 AC Max; 1/2 AC Max Impervious	Drainage Area For Infiltration Design (Per Practice)
20%	Max. Slope of Site
3'	Min. Depth to Bedrock & Seasonally High Water Table
A,B - Normal	NRCS Soil Type *can be used in C&D soil types with modifications (e.g. under-drains)
Good	Freeze/ Thaw Suitability
Suitable	Potential Hotspot Runoff *requires impermeable liner

STORM SEQUENCE

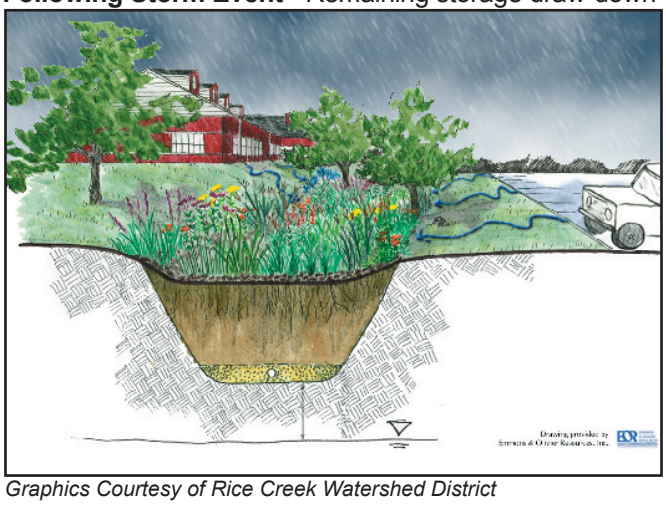
Start of Storm Event - Initial runoff & storage



Duration of Storm Event - Storage & filtration/infiltration



Following Storm Event - Remaining storage draw-down



Graphics Courtesy of Rice Creek Watershed District

Description:

In general, bioretention systems can be described as shallow, landscaped depressions commonly located in parking lot islands or within small pockets in residential areas that receive stormwater runoff (Metropolitan Council Small Sites BMP Manual, 2001).

Bioretention facilities capture rainwater runoff to be filtered through a prepared soil medium. Once the soil pore space capacity of the medium is exceeded, stormwater begins to pool at the surface of the planting soil. Pollutants are removed by a number of processes including adsorption, filtration, volatilization, ion exchange and decomposition (Prince George's County, MD, 1993). Filtered runoff can either be allowed to infiltrate into the surrounding soil (functioning as an infiltration basin or rainwater garden), or collected by an under-drain system and discharged to the storm sewer system or directly to receiving waters (functioning like a surface sand filter). Runoff from larger storms is generally diverted past the area to the storm drain system (Metropolitan Council Small Sites BMP Manual, 2001).

Bioretention is a stormwater treatment practice that utilizes the chemical, biological and physical properties of plants, microbes and soils for capturing/ reducing stormwater runoff and removing pollutants from runoff. This process is often incorporated into many different types of filtration and infiltration stormwater treatment practices.

A. Suitability

General

Bioretention areas are suitable stormwater treatment practices for all land uses, as long as the contributing drainage area is appropriate for the size of the facility. Common bioretention opportunities include landscaping islands, cul-de-sacs, parking lot margins, commercial setbacks, open space, and street-scapes (i.e., between the curb and sidewalk). Bioretention, when designed with an underdrain and liner, is also a good design option for treating potential stormwater hotspots (PSHs). Bioretention is extremely versatile because of its ability to be incorporated into landscaped areas. The versatility of the practice also allows for bioretention areas to be frequently employed as stormwater retrofits.

Function Within Stormwater Treatment Train

Unlike end-of-pipe BMPs, bioretention facilities are typically shallow depressions located in upland areas. The strategic, uniform distribution of bioretention facilities across a development site results in smaller, more manageable subwatersheds, and thus, will help in controlling runoff close to the source where it is generated (Prince George's County Bioretention Manual, 2002).

Bioretention facilities are designed to function by essentially mimicking certain physical, chemical, and biological processes that occur in the natural environment. Depending upon the design of a facility, different processes can be maximized or minimized depending on the type of pollutant loading expected (Prince George's County Bioretention Manual – 2002).

Inver Grove Heights Permit Applicability

One of the goals of this manual is to facilitate an understanding of and compliance with the city of Inver Grove Heights' Volume Control Standard. This standard must be met on all new and re-development projects taking place in the northwest area.

Bioretention systems that incorporate infiltration may reduce the 5-year 24-hour infiltration standard by the amount that the practice is able to store and infiltrate. Small-scale bioretention areas are expected to make up a large portion of the 5-year 24-hour infiltration standard. Bioretention devices may also be used to meet the Inver Grove Heights pretreatment requirements. (Chapter 6)

The following terms are thus used in the text to distinguish various levels of green roof design guidance:

REQUIRED:	Indicates design standards stipulated by the IGH PUD.
HIGHLY RECOMMENDED:	Indicates design guidance that is extremely beneficial or necessary for proper functioning of the practice, but is not specifically required by the City of Inver Grove Heights.
RECOMMENDED:	Indicates design guidance that is helpful for performance but not critical to the design.

Design Variants

Alternative Names

As bioretention becomes a more common tool in the stormwater management toolbox and as the number of design variants increases, so does the number of names for each of these variants.

As an example of the ongoing evolution of bioretention terminology, the terms “Raingarden” and “Rainwater Garden” have recently caught on with the public and are being used interchangeably with Bioretention. In most instances, Raingarden designs are utilizing the processes of bioretention, but the term Raingarden is also being loosely used to describe BMPs that are operating more as stormwater ponds (or as other BMPs) than as bioretention facilities.

Further confusion stems from using the terms “process” and “practice” interchangeably. As mentioned earlier, bioretention is not a “practice” per se but rather a process or group of processes that can be incorporated into many different practices.

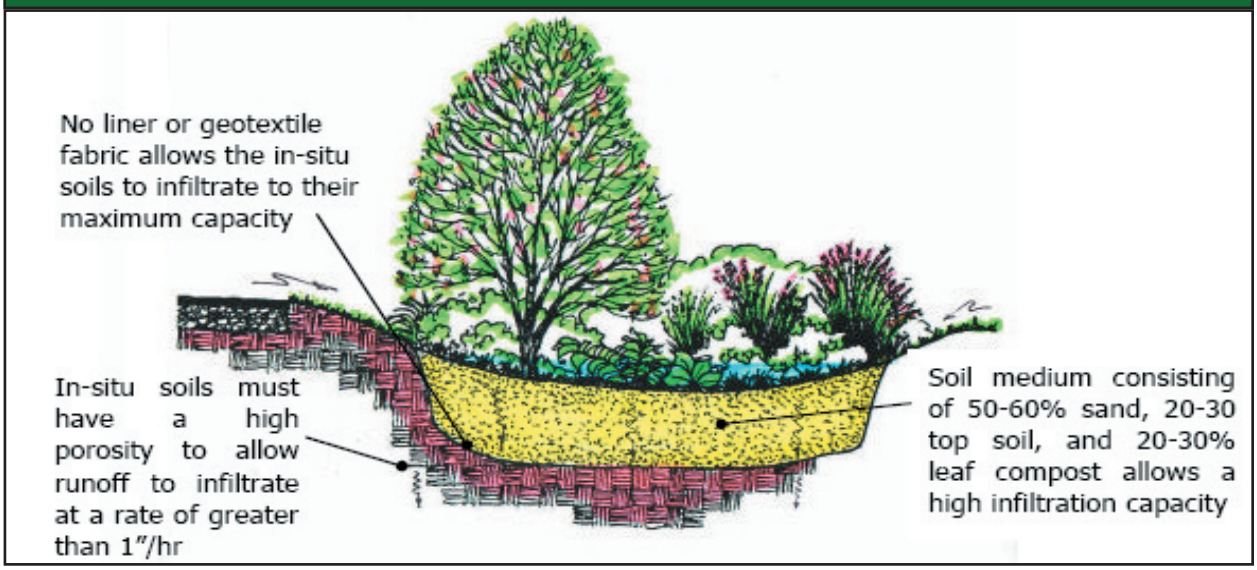
This section of is provided to clarify the more common bioretention terminology being used in the field of stormwater management today.

Performance Types (adapted from Prince George’s County 2002)

The following facility performance types have been slightly modified for Minnesota to optimize the expected or anticipated pollutant loadings based on the proposed land use. All of these facilities may be used as high-hydraulic-capacity filtration systems. High-hydraulic-capacity filtration systems are defined as systems that are composed of essentially a shallow sandy soil mix, thick layer of mulch and an underdrain/gravel discharge system.

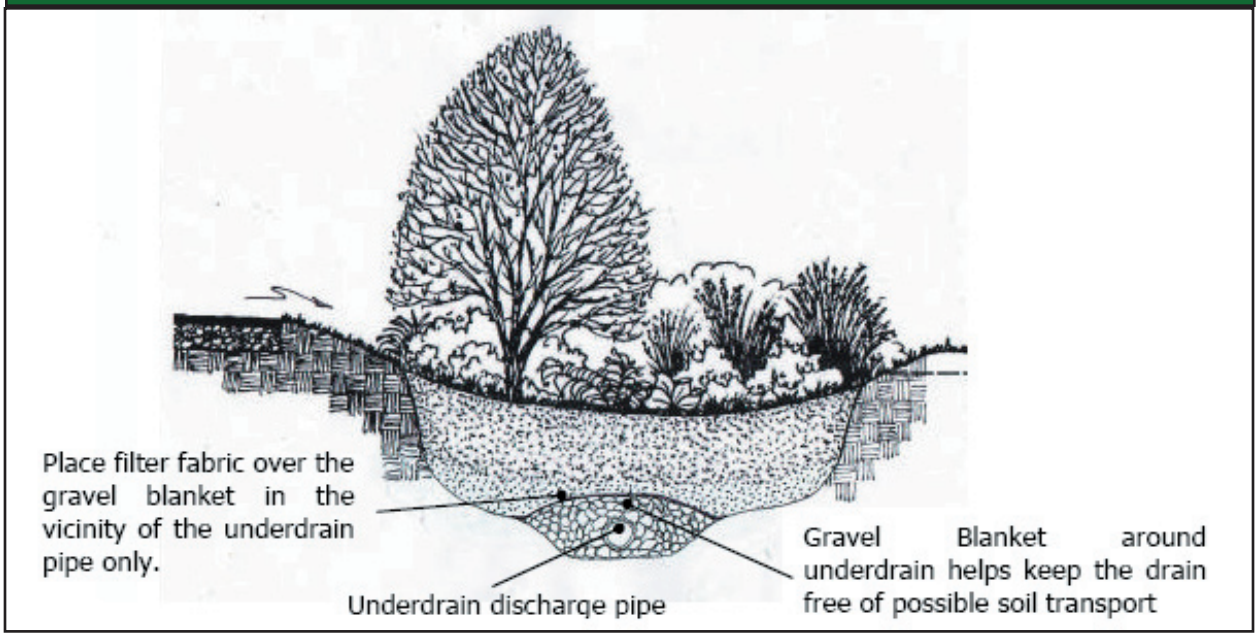
- ***Infiltration / Recharge Facility -*** This type of facility is suitable for areas where high recharge of groundwater would be beneficial. Because there is no underdrain, the in-situ soils need to have a high infiltration rate to accommodate the inflow levels. The infiltration rate of the in-situ soils must be determined through proper soil testing/diagnostics. Preferably, facilities of this type should have infiltration rates of 1”/hr or greater. Facilities must be at least 2.5 feet deep to allow adequate filtration processes to occur. Siting of these facilities should be in areas where visibility is not a concern because hydraulic overload can cause extended periods of standing water conditions. This facility type is suitable for areas and land uses that are expected to generate nutrient runoff (i.e.; residential and business campuses) that can be infiltrated and captured by the facility. Fresh mulch rather then aged shredded bark mulch can be used to enhance denitrification processes.

Figure 8.5 Infiltration / Recharge Facility



Source: Prince George’s County Bioretention Manual - 2002

Figure 8.6 Filtration/Partial Recharge Facility

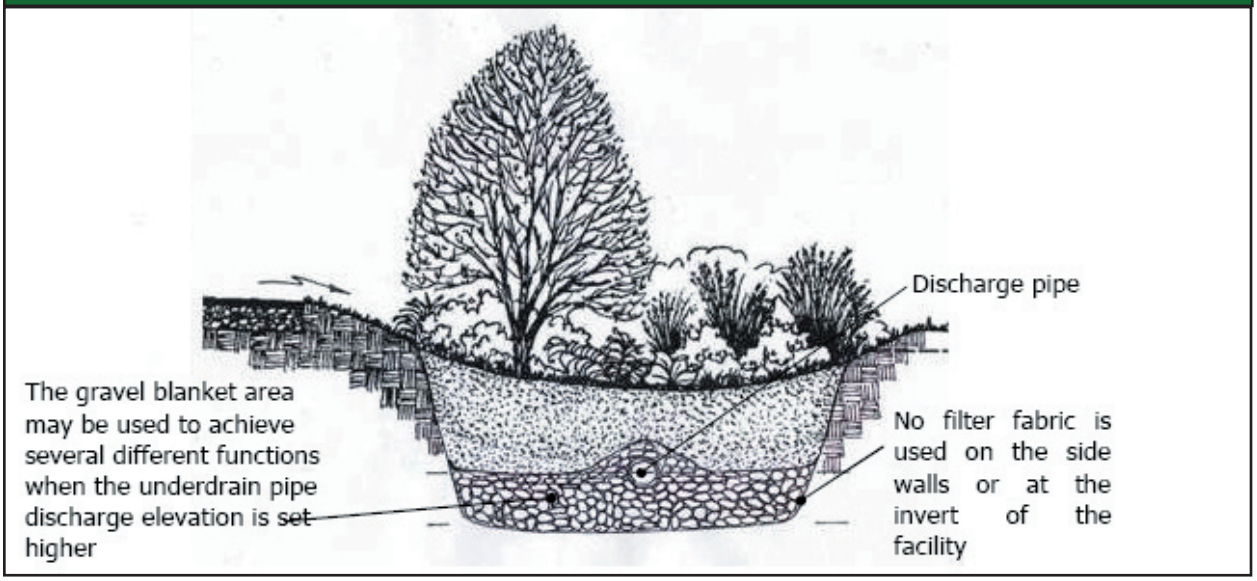


Source: Prince George's County Bioretention Manual - 2002

- ***Filtration/Partial Recharge Facility –*** This type of facility is suitable for areas where high filtration and partial recharge of runoff would be beneficial. This facility is designed with an underdrain at the invert of the planting soil mix to ensure that the facility drains at a desired rate. The facility allows for partial recharge, as an impervious liner is not used. The depth is also shallow (2.5') to allow the facility to handle high capacity flows if necessary. Siting of this performance type is suitable for visually prominent or gateway locations in a community. The facility type is suitable for areas and land uses that are expected to generate nutrient and metals loadings (residential, business campus, or parking lots). Attention to mulch type and amount will ensure the adequate treatment of the anticipated loadings. The facility shown in Figure 8.6 incorporates a filter material between the gravel blanket around the underdrain and the planting soil above. The filter fabric does not need to extend to the side walls. The filter fabric may be installed horizontally above the gravel blanket- extending just 1-2 feet on either side of the underdrain pipe below. Do ***not*** wrap the underdrain with filter fabric. Instead of using a filter fabric, the designer may opt to utilize a pea gravel diaphragm over the underdrain gravel blanket. This type of facility is also recommended for tight impermeable soils where infiltration is limited. Some volume reduction will be seen from evapotranspiration.

- ***Infiltration/Filtration/Recharge*** – This type of facility is recommended for areas where higher nutrient loadings (particularly nitrates) are anticipated. The facility is designed to incorporate a fluctuating aerobic/anaerobic zone below the raised underdrain discharge pipe. This fluctuation created by saturation and infiltration into the surrounding soils will achieve de-nitrification. With a combination of a fresh mulch covering, nitrates will be mitigated through the enhancement of natural denitrification processes. This type of facility would be suitable for areas where nitrate loadings are typically a problem (residential communities). The raised underdrain has the effect of providing a storage area below the invert of the underdrain discharge pipe. This area provides a recharge zone and quantity control can also be augmented with this storage area. The storage area is equal the void space of the material used.

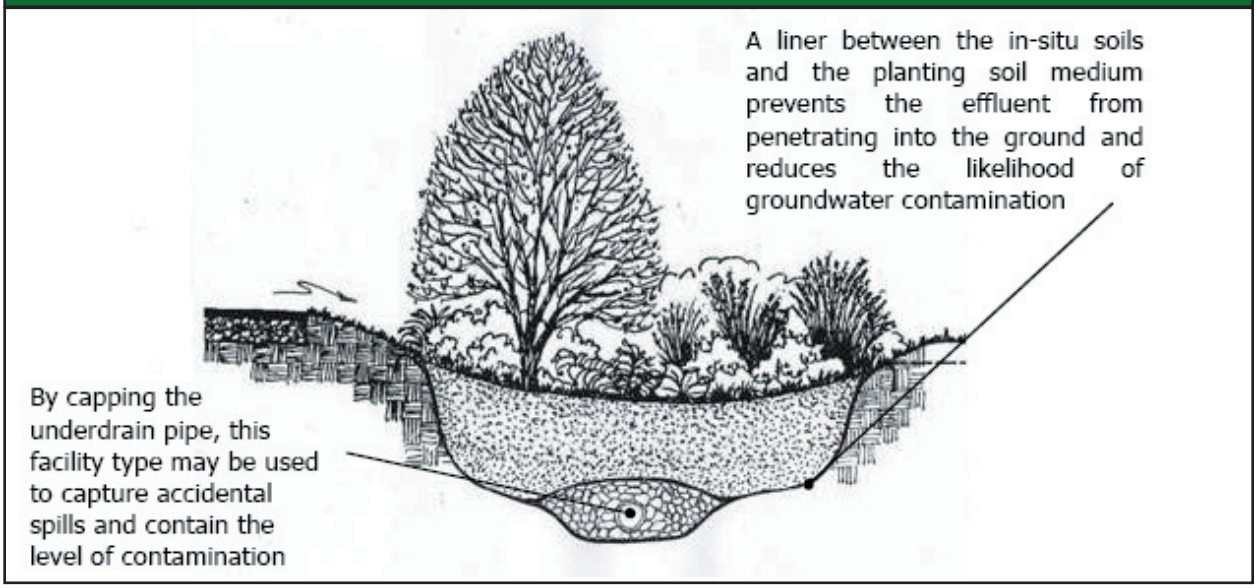
Figure 8.7 Infiltration/Filtration/Recharge Facility



Source: Prince George's County Bioretention Manual - 2002

Filtration Only – This type of facility is recommended for areas that are known as "hot-spots" (gas stations, transfer sites, and transportation depots). An important feature of this type of facility is the impervious liner designed to reduce or eliminate the possibility of groundwater contamination. The facility provides a level of treatment strictly through filtration processes that occur when the runoff moves through the soil material to the underdrain discharge point. In the event of an accidental spill, the underdrain can be blocked and the objectionable materials siphoned through the observation well and safely contained.

Figure 8.8 Filtration Only Facility



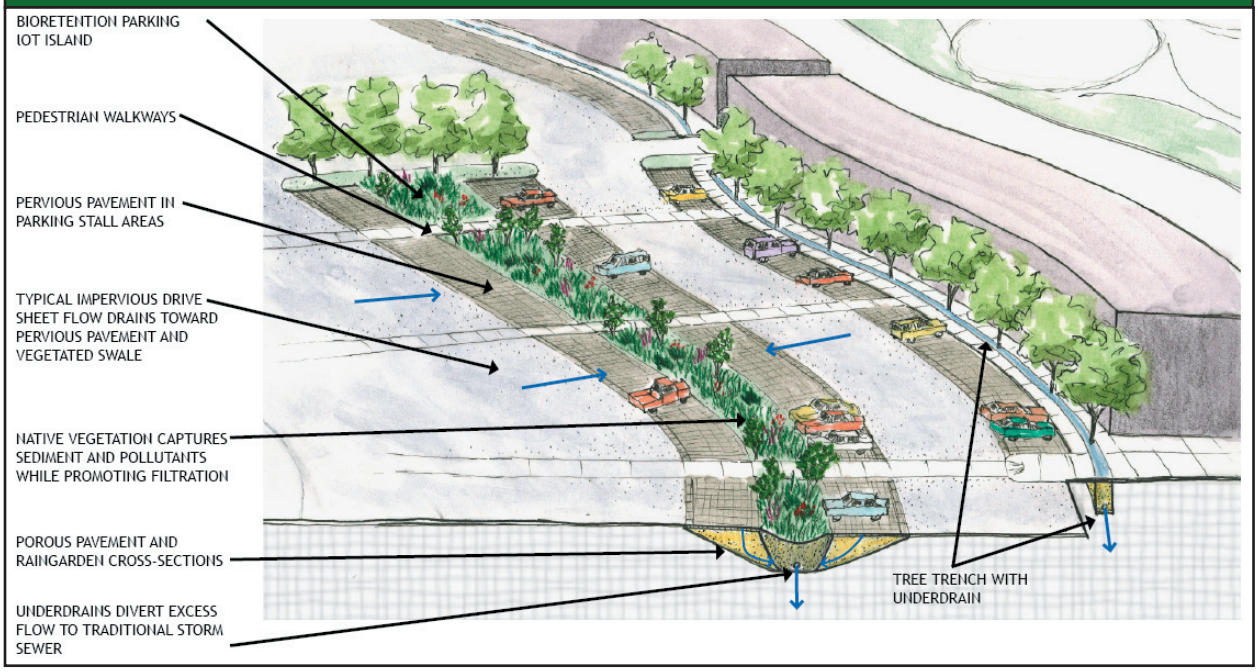
Source: Prince George's County Bioretention Manual - 2002

Design Types for Various Land Uses

It should be noted that the layout of the bioretention area will vary according to individual sites, and to specific site constraints such as underlying soils, existing vegetation, drainage, location of utilities, sight distances for traffic, and aesthetics. Designers are encouraged to be creative in determining how to integrate bioretention into their respective site designs. With this in mind, the following conceptual illustrations are presented as alternative options.

- ***On-lot / Raingarden –*** Simple design that incorporates a planting bed in the low portion of the site. On-lot systems are designed to receive flows from gutters, and/or other impervious surfaces.
- ***Parking Lot Islands (Curbless)*** – In a paved area with no curb, pre-cast car stops or a "ribbon curb" can be installed along the pavement perimeter to protect the bioretention area. This application of bioretention should only be attempted where shallow grades allow for sheet flow conditions over level entrance areas. Water may be pooled into the parking area where parking spaces are rarely used, to achieve an element of stormwater quantity control beyond the confines of the bioretention surface area (Prince George's County 2002).
- ***Parking Lot Islands (Curb cut)*** – For curb-cut entrance approaches, the water is diverted into the bioretention area through the use of an inlet deflector block, which has ridges that channel the runoff into the bioretention area (Prince George's County 2002). Special attention to erosion control and pretreatment should be given to the concentrated flow produced by curb cuts. Figure 8.9 features a parking lot island bioretention facility in context with other stormwater BMPs.

Figure 8.9 Parking Lot Island Bioretention Facility



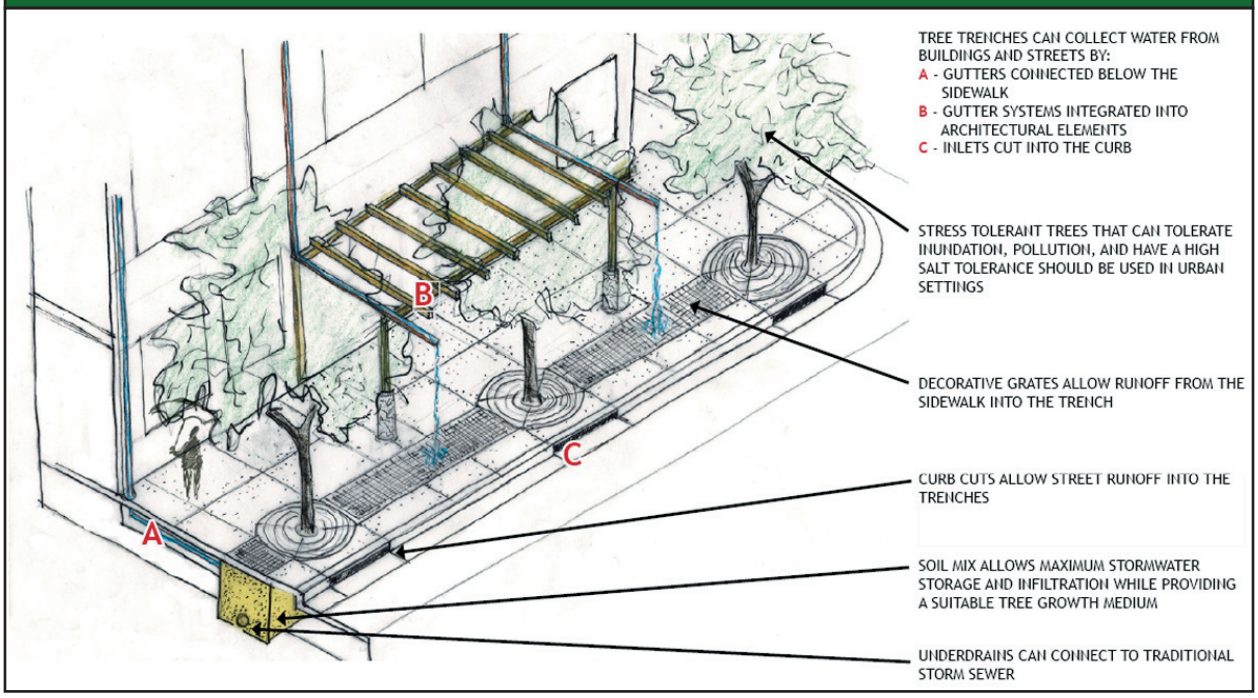
- ***Road Medians / Traffic Islands –*** Create a multifunctional landscape by utilizing road medians and islands for bioretention. There is no minimum width recommended for traffic islands from street edge to edge. A buffer may be necessary along the outside curb perimeter to minimize the possibility of drainage seeping under the pavement section, and creating "frost heave" during winter months. Alternately, the installation of a geotextile filter fabric "curtain wall" along the perimeter of the bioretention island will accomplish the same effect.

- ***Tree Pits / Tree Box Filters –*** Tree Pits and Tree Box Filters afford many opportunities for bioretention. Designs vary widely from simple "tree pits", used for local drainage interception to more formal Tree Box Filters, which are a useful tool for highly urbanized streetscapes.

The Tree Pit technique provides very shallow ponding storage areas in a "dished" mulch area around the tree or shrub. Typically, the mulched area extends to the dripline for the tree and is similar to conventional mulching practices, except that the mulch area is depressed at least 2-3" rather than mounded around the tree (Low Impact Development Center – 2005).

Tree Box Filters are bioretention areas installed beneath trees that can be very effective at controlling runoff, especially when distributed throughout the site. Runoff is directed to the tree box, where it is cleaned by vegetation and soil before entering a catch basin. The runoff collected in the tree-boxes helps irrigate the trees. The system consists of a container filled with a soil mixture, a mulch layer, under-drain system and a shrub or tree. Stormwater runoff drains directly from impervious surfaces through a filter media. Treated water flows out of the system through an under drain connected to a storm drainpipe / inlet or into the surrounding soil. Tree box filters can also be used to control runoff volumes / flows by adding storage volume beneath the filter box with an outlet control device (Low Impact Development Center – 2005). Figure 8.10 details a Tree Box Filters in a chain.

Figure 8.10 Tree Box Filteres



Retrofit Suitability

The ability to use bioretention as a retrofit often depends on the age of development within a subwatershed. Subwatersheds that have been developed over the last few decades often present many bioretention opportunities because of open spaces created by modern setback, screening and landscaping requirements in local zoning and building codes. However, not every open area will be a good candidate for bioretention due to limitations associated with existing inverts of the storm drain system and the need to tie the under drain from the bioretention area into the storm drain system. In general, four to six feet of elevation above this invert is needed to drive storm water through the proposed bioretention area.

Cold Climate Suitability

Little research exists on the cold climate effectiveness of bioretention devices. Some believe that bioretention can be of marginal effectiveness for treating snowmelt runoff because of the dormancy of the vegetation during the cold season. However, the incorporation of some sump storage into the design of any bioretention system will provide an opportunity to route and collect snowmelt runoff and begin the filtration and infiltration processes. The incorporation of some storage as part of the system (for example, setting the outlet elevation 6" to 12" above the bottom of the bioretention device) is necessary for this adaptation. Once relatively "warm" snowmelt runoff begins to accumulate in a bioretention system, some downward migration will likely begin and the system will activate. A system that is relatively dry when winter begins will respond more quickly and treat spring runoff more effectively once melt begins (see Chapter 6 for Cold Climate discussions).

Water Quantity Treatment

Bioretention practices are not typically suitable for providing complete water quantity control, but can be used to infiltrate a portion of the Inver Grove Heights Volume Control Standard (VCS). They are normally either designed off-line using a flow diversion or configured to safely pass large storm flows while still protecting the ponding area, mulch layer and vegetation. Experience and modeling analysis have shown that bioretention can be used for stormwater management quantity control when facilities are distributed throughout a site to reduce runoff and maintain the preexisting time of concentration. This effort can be incorporated into the site hydrologic analysis

Water Quality Treatment

Bioretention is an excellent stormwater treatment practice due to the variety of pollutant removal mechanisms including vegetative filtering, settling, evaporation, infiltration, transpiration, biological and microbiological uptake, and soil adsorption. Pollutant removal and effluent concentration data for select parameters are provided in Tables 8.19 and 8.20, respectively. Bioretention can also be designed as an effective infiltration / recharge practice, particularly when parent soils have high permeability (> ~ 0.5 in/hr). Where soils are not favorable, a rock infiltration gallery can be used to promote slow infiltration / recharge of stored water.

Table 8.19 Percent Removal of Key Pollutants by Bioretention

Practice	TSS [%]	Total Phosphorus [%]	Total Nitrogen [%]	Metals[2] [%]	Bacteria [%]	Hydro-carbons [%]
Bioretention1	85*	65	50	95	35*	80*

1. Based on fewer than five data points (i.e., independent monitoring studies)
2. Average of zinc and copper
* Assumed values based on filtering practice performance

Source: Winer, 2000

Table 8.20 Typical BMP Best Achievable Effluent Concentrations

Practice	TSS	TP	TN	Cu[1]	Zn[1]
Bioretention	11	0.3	1.1[2]	7	40

1. Units for Zn and Cu are micrograms per liter
* Assumed values based on filtering practice performance

Source: Winer, 2000

Early bioretention facilities were designed to provide water quality benefits by controlling the "first flush" event. Using highly permeable planting soils and an underdrain, however, creates a high-rate biofilter, which can treat 90-95% (or higher) of the total annual volume of rainfall/runoff. Furthermore, monitoring has shown the pollutant removal rates to be significantly above the estimates presented in the original manual (Prince George's County 2002).

Limitations

The following general limitations should be recognized when considering installation of a bioretention practice:

- Non traditional stormwater management technique;
- Maintenance personnel may need additional instruction on routine Operation and Maintenance requirements;
- Lack of long-term performance and operation and management information.

B. Major Design Elements

Physical Feasibility Initial Check

Before deciding to use a bioretention device for stormwater management, it is helpful to consider several items that bear on the feasibility of using such a device at a given location. The following list of considerations will help in making an initial judgment as to whether or not a bioretention device is the appropriate BMP for the site.

- ***Drainage Area*** – 5 acres maximum RECOMMENDED (0.5 to 2 acres is ideal). For larger sites, multiple bioretention areas can be used to treat site runoff provided appropriate grading is present to convey flows.
- ***Site Topography and Slopes*** – It is RECOMMENDED that sloped areas immediately adjacent to the bioretention practice be less than 20% but greater than 1%, to promote positive flow towards the practice.
- ***Soils*** – No restrictions; engineered media HIGHLY RECOMMENDED; underdrain is HIGHLY RECOMMENDED where parent soils are HSG C or D.
- ***Depth to Groundwater and Bedrock*** – A separation distance of 3 feet is REQUIRED between the bottom of the bioretention facility and the elevation of the seasonally high water table or bedrock.
- ***Site Location/Minimum Setbacks*** – A minimum 10 foot separation from building foundations is REQUIRED, with slopes directed away from building.

Conveyance

It is HIGHLY RECOMMENDED that overflow associated with the 10- or 25-year storm (depending on local drainage criteria) be controlled such that velocities are non-erosive at the outlet point (to prevent downstream slope erosion), and that when discharge flows exceed 3 cfs, the designer evaluate the potential for erosion to stabilized areas and bioretention facilities.

Common overflow systems within the structure consist of a yard drain inlet, where the top of the yard drain inlet is placed at the elevation of the shallow ponding area. A stone drop of about twelve inches or small stilling basin could be provided at the inlet of bioretention areas where flow enters the practice through curb cuts or other concentrated flow inlets. In cases with significant drop in grade this erosion protection should be extended to the bottom of the facility.

It is HIGHLY RECOMMENDED that bioretention areas with underdrains be equipped with a minimum 8" diameter underdrain in a 1' deep gravel bed. Increasing the diameter of the underdrain makes freezing less likely, and provides a greater capacity to drain standing water from the filter. The porous gravel bed prevents standing water in the system by promoting drainage. Gravel is also less susceptible to frost heaving than finer grained media. It is also HIGHLY RECOMMENDED that a pea gravel diaphragm and/or permeable filter fabric be placed between the gravel layer and the filter media.

Pretreatment

Adequate pretreatment for bioretention systems is REQUIRED. It is HIGHLY RECOMMENDED that pretreatment incorporate as many of the following as are feasible:

- grass filter strip below a level spreader or grass channel
- gravel diaphragm
- a mulch layer.

If bioretention is used to treat runoff from a parking lot or roadway that is frequently sanded during snow events, there is a high potential for clogging from sand in runoff. It is HIGHLY RECOMMENDED that grass filter strips or grass channels at least 10 or 20 feet long, respectively, convey flow to the system in these situations. Local requirements may allow a street sweeping program as an acceptable pretreatment practice.

Treatment

The following guidelines are applicable to the actual treatment area of a bioretention facility:

- ***Space Required*** – It is RECOMMENDED that approximately 7-10% of the tributary impervious area be dedicated to the practice footprint; with a minimum 200 square foot area for small sites (equivalent to 10 feet x 20 feet)
- ***Practice Slope –*** It is RECOMMENDED that the slope of the surface of the bioretention practice not exceed 1%, to promote even distribution of flow throughout.
- ***Depth*** – It is RECOMMENDED that the elevation difference from the inflow to the outflow be approximately 4-6 feet when an underdrain is used.
- ***Groundwater Protection*** – Exfiltration of unfiltered PSH runoff into groundwater is prohibited.

It is HIGHLY RECOMMENDED that bioretention not be used on sites with a continuous flow from groundwater, sump pumps, or other sources. The following treatment design components for bioretention systems are also HIGHLY RECOMMENDED:

- 2.5 to 4 foot deep planting soil bed (i.e., "filter bed")
- surface mulch layer
- 6-18 inch deep surface ponding area
- surface ponding of up to 12 inches may be allowed in areas with shallow bedrock.

Elevations must be carefully worked out to ensure that the desired runoff flow enters the facility with no more than the maximum design depth. The bioretention area should be sized based on the principles of Darcy's Law. A coefficient of permeability k = 0.5 ft/day is appropriate to characterize the planting medium / filter media soil (Claytor and Schueler, 1996). This value is conservative to account for clogging associated with accumulated sediment.

It is REQUIRED that the design permeability rate through the planting soil bed be high enough to fully drain the stormwater quality design storm runoff volume within 72 hours (48 hours if its being used to meet MPCA requirements). It is HIGHLY RECOMMENDED that this permeability rate must be determined by field or laboratory testing.

When using bioretention to treat PSHs, particularly in sensitive watersheds, it is HIGHLY RECOMMENDED that additional practices be incorporated as a treatment train for at least limited treatment during the winter when the bioretention area may be frozen.

Landscaping

It is REQUIRED that impervious area construction be completed and pervious areas established with dense and healthy vegetation prior to introduction of stormwater into a bioretention practice. Landscaping is critical to the performance and function of bioretention areas. Therefore, a landscaping plan is REQUIRED for bioretention areas. RECOMMENDED planting guidelines for bioretention facilities are as follows:

- Vegetation should be selected based on a specified zone of hydric tolerance. *Plants for Stormwater Design* by the Minnesota Pollution Control Agency is a good resource.
- Native plant species should be specified over non-native species. Hardy native species that thrive in our ecosystem without chemical fertilizers and pesticides are the best choices.
- Many bioretention facilities feature wild flowers and grasses as well as shrubs and some trees.
- Woody vegetation should not be specified at inflow locations.
- Trees should not be planted directly overtop of underdrains and may be best located along the perimeter of the practice.
- Salt resistant vegetation should be used in locations with probable adjacent salt application, i.e. roadside, parking lot, etc.
- Fluctuating water levels following seeding (prior to germination) can cause seed to float and be transported. Seed is also difficult to establish through mulch, a common surface component of Bioretention. It may take up to two growing seasons to establish the function and desired aesthetic of mature vegetation via seeding. Therefore mature plantings are recommended over seed.
- If a minimum coverage of 50% is not achieved after the first growing season, a reinforcement planting is required
- Bioretention area locations should be integrated into the site planning process, and aesthetic considerations should be taken into account in their siting and design.

Safety

Bioretention practices do not pose any major safety hazards. Trees and the screening they provide may be the most significant consideration of a designer and landscape architect. Where inlets exist, they should have grates that either have locks or are sufficiently heavy that they cannot be removed easily. Standard inlets and grates used by Mn/DOT and local jurisdictions should be adequate. Fencing of bioretention facilities is generally not desirable

Construction Details

Soil Medium / Filter Media Content

A well blended, homogenous mixture of 50-60% construction sand: 20-30% top soil; and 20-30% organic leaf compost is necessary to provide a soil medium with a high infiltration/filtration capacity.

- ***Sand*** - AASHTO M-6 or ASTM C-33 with grain size of 0.02”- 0.04”
- ***Top Soil*** - sandy loam, loamy sand, or loam texture per USDA textural triangle with less than 5% maximum clay content
- ***Organic Leaf Compost*** - (MnDOT Grade 2)

Soil Medium / Filter Media Depth

Field experiments show that pollutant removal is accomplished within the top 30” of soil depth with minimal additional removal beyond that depth (Prince George’s County 2002). Therefore, the recommended depth

of the prepared soil is 30 inches. However, if large trees are preferred in the design, a soil depth of 48”-52” should be utilized. The soil depth generally depends upon the root depth of the prescribed vegetation and content of underlying soils.

Gravel Filter Specifications - Underdrain gravel blanket shall be double washed stone, 1-1/2” in size. Pea Gravel shall be washed, river-run, round diameter, ¼ - ½ in size.

Mulch Content and Depth - Fresh shredded bark mulch (Mn/DOT Type 6) should be used when possible to maximize nitrogen retention. If aged mulch is used, use the shredded type instead of the “chip” variety to minimize floating action. The mulch layer should not exceed 3” in depth. Too much mulch can restrict oxygen flow to roots. In addition, mulch should not be mounded around the base of plants since this encourages damage from pests and diseases.

C. Construction Specifications

Given that the construction of bioretention practices incorporates techniques or steps which may be considered non-traditional, it is recommended that the construction specifications include the following format and information.

I. Temporary Erosion Control
- ► Install prior to site disturbance
- ► Protect catch basin/inlet
- ► It is HIGHLY RECOMMENDED that future bioretention locations not be used as temporary sedimentation basins. If used as temporary sedimentation basins, the bioretention facility should be over excavated a minimum of 18” below sedimentation basin grade.

II. Excavation, Backfill and Grading
- ► Timing of grading of infiltration practices relative to total site development
- ► Use of low-impact, earth moving equipment
- ► Do not over-excavate
- ► Restoration in the event of sediment accumulation during construction of practice
- ► Gravel backfill specifications
- ► Gravel filter specifications
- ► Filter fabric specifications

III. Native Plants, Planting and Transplanting (MN Plant List in Appendix E of the Manual)
- ► Site preparation of planting areas
- ► Timing of native seeding and native planting
- ► Weed control
- ► Watering of plant material

IV. Construction Sequence Scheduling
- ► Temporary construction access
- ► Location of silt fence installation to protect BMPs and downstream receiving waters
- ► Removal and storage of excavated material
- ► Installation of underground utilities
- ► Rough grading
- ► Seeding and mulching disturbed areas
- ► Road construction
- ► Final grading
- ► Site stabilization
- ► Installation of semi-permanent and permanent erosion control measures
- ► Silt fence removal

V. Construction Observation
- ► Adherence to construction documents
- ► Verification of physical site conditions
- ► Erosion control measures installed appropriately

D. Operation and Maintenance

Overview

The most frequently cited maintenance concern for bioretention is surface and underdrain clogging caused by organic matter, fine silts, hydrocarbons, and algal matter. Common operational problems include:

- ► standing water
- ► clogged filter surface
- ► inlet, outlet or underdrains clogged

Design Phase Maintenance Considerations

Implicit in the design guidance in the previous sections is the fact that many design elements of bioretention systems can minimize the maintenance burden and maintain pollutant removal efficiency. Key examples include: limiting drainage area, providing easy site access (REQUIRED), providing pretreatment (REQUIRED), and utilizing native plantings.

Construction Phase Maintenance

Proper construction methods and sequencing play a significant role in reducing problems with operation and maintenance (O&M). In particular, with construction of bioretention practices the most important action for preventing operation and maintenance difficulties is to ensure that the contributing drainage area has been fully stabilized prior to bringing the practice on line (this is a REQUIRED practice).

Inspections during construction are REQUIRED to ensure that the bioretention practice is built in accordance with the approved design and standards and specifications. Detailed inspection checklists should be used that include sign-offs by qualified individuals at critical stages of construction, to ensure that the contractor's interpretation of the plan is acceptable to the professional designer. An example construction phase inspection checklist is provided in Appendix D.

Post-construction Operation and Maintenance

A maintenance plan clarifying maintenance responsibility is REQUIRED. Effective long-term operation of bioretention practices necessitates a dedicated and routine maintenance schedule with clear guidelines and schedules. Some important post-construction considerations are provided below along with RECOMMENDED maintenance standards. A more detailed checklist of maintenance activities and associated schedules is provided in Appendix F.

- ► A site specific O&M plan that includes the following considerations should be prepared by the designer prior to putting the stormwater filtration practice into operation:
    - Operating instructions for outlet component
    - Vegetation maintenance schedule
    - Inspection checklists
    - Routine maintenance checklists
- ► A legally binding and enforceable maintenance agreement should be executed between the practice owner and the City of Inver Grove Heights.

- Adequate access must be provided for all bioretention facilities for inspection, maintenance, and landscaping upkeep, including appropriate equipment and vehicles.
- The surface of the ponding area may become clogged with fine sediment over time. Core aeration or cultivating of non-vegetated areas may be required to ensure adequate filtration.
- Bioretention areas should not be used as dedicated snow storage areas.
    - Areas designed for infiltration should be protected from excessive snow storage where sand and salt is applied
    - Specific soil storage areas should be assigned that will provide some filtration before the storm water reaches the infiltration areas.
    - When used for snow storage, or if used to treat parking lot runoff, the bioretention area should be planted with salt tolerant, and non-woody plant species

- Bioretention areas should always be inspected for sand build-up on the surface following the spring melt event.
- General maintenance activities and schedule are provided in Table 8.21.

Table 8.21 Recommended Maintenance Activities for Bioretention Areas

Activity	Schedule
► Pruning and weeding to maintain appearance. ► Mulch replacement when erosion is evident. ► Remove trash and debris. ► Mow filter strip.	As needed
► Inspect inflow points for clogging (off-line systems). Remove any sediment. ► Inspect filter strip/grass channel for erosion or gullying. Re-seed or sod as necessary. ► Trees and shrubs should be inspected to evaluate their health and remove any dead or severely diseased vegetation.	Semi-annually
► Inspect and remove any sediment and debris build-up in pretreatment areas. ► Inspect inflow points and bioretention surface for build up of road sand associated with spring melt period. Remove as necessary and replant areas that have been impacted by sand/salt build up.	Annually
► Replace mulch over the entire area. ► Replace pea gravel diaphragm or filter fabric if warranted. ► The planting soils should be tested for pH to establish acidic levels. If the pH is below 5.2, limestone should be applied. If the pH is above 7.0 to 8.0, then iron sulfate plus sulfur can be added to reduce the pH.	2 to 3 years

Construction and Maintenance Costs

Once the construction plans are created, designers should utilize Table 8.22 and the cost estimation worksheet in Appendix F.

Table 8.22 lists the specific site components that are specific to bioretention devices. Not included in this table are those cost items that are common to all construction projects, such as mobilization, traffic control, erosion and sediment control, permitting, etc. A more detailed worksheet, utilizing 2005 construction prices, is contained in Appendix F.

Table 8.22 Cost Components for Bioretention Devices

Implementation Stage	Primary Cost Components	Basic Cost Estimate	Other Considerations
Site Preparation	Tree & plant protection	Protection Cost ($/area) x Affected Area	Removal of existing structures, topsoil removal and stockpiling
	Clearing & grubbing	Clearing Cost ($/area) x Affected Area	
	Topsoil salvage	Clearing cost ($/area) x Affected Area	
Site Formation	Excavation / grading	4-ft Depth Excavation Cost ($/acre) x Area (acre)	Soil & rock fill material, tunneling
	Hauling material offsite	Excavation Cost x (% of Material to be hauled away)	
Structural Components	Underdrains	Underdrain cost ($/lineal foot) x length of device	Pipes, catchbasins, manholes, valves
	Inlet structure	($/structure) or ($/curb cut)	
	Outlet structure	($/structure)	
Site Restoration	Filter strip	Sod cost ($/square foot) x filter strip area	Tree protection, soil amendments, seed bed preparation, trails
	Soil preparation	Topsoil or amendment cost ($/acre) x Area (acre)	
	Seeding	Seeding Cost ($/acre) x Seeded Area (acre)	
	Planting / transplanting	Planting Cost ($/acre) x Planted Area (acre)	
Annual Operation, Maintenance, and Inspection	Debris removal	Removal Cost ($/acre) x Area (acre) x Frequency (2x / 1yr)	Vegetation maintenance, cleaning of structures
	Sediment removal	Removal Cost ($/acre) x Area (acre) x Frequency (1x / 5yr)	
	Weed control	Labor cost ($/hour) x Hours per visit x Frequency (4x per year)	
	Inspection	Inspection Cost ($) x Inspection Frequency (6x / 1 yr)	
	Mowing	Mowing Cost ($) x Mowing Frequency (4x / 1 yr)	

Source: Adapted from EPA, 1999

E. Design Procedure

The following steps outline a recommended design procedure for bioretention practices in compliance with the Inver Grove Heights stormwater permit. Design recommendations beyond those specifically required by the permit are also included and marked accordingly.

Design Steps

Step 1. Make a preliminary judgment as to whether site conditions are appropriate for the use of an bioretention practice, and identify the function of the practice in the overall treatment system

A. Consider basic issues for initial suitability screening

- ► Site drainage area
- ► Site topography and slopes
- ► Soil infiltration capacity
- ► Regional or local depth to groundwater and bedrock
- ► Site Location/Minimum setbacks

B. Determine how the bioretention practice will fit into the overall stormwater treatment system

- ► Decide whether the bioretention practice is the only BMP to be employed, or if are there other BMPs addressing some of the treatment requirements.
- ► Decide where on the site the bioretention practice is most likely to be located.

Step 2. Confirm design criteria and applicability.

A. Check with local officials, WMOs, and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.
B. Determine whether the bioretention practice must comply with the MPCA Permit.

Step 3. Perform field verification of site suitability

- ► If the initial evaluation indicates that a bioretention practice would be a good BMP for the site, it is HIGHLY RECOMMENDED that a minimum of three soil borings or pits be dug (in the same location as the proposed bioretention practice) to verify soil types and infiltration capacity characteristics and to determine the depth to groundwater and bedrock.
- ► It is HIGHLY RECOMMENDED that the minimum depth of the soil borings or pits be five feet below the bottom elevation of the proposed bioretention practice.
- ► It is HIGHLY RECOMMENDED that soil profile descriptions be recorded and include the following information for each soil horizon or layer (Source: Site Evaluation for Stormwater Infiltration, Wisconsin Department of Natural Resources Conservation Practice Standards 2004):
    - Thickness, in inches or decimal feet
    - Munsell soil color notation
    - Soil mottle or redoximorphic feature color, abundance, size and contrast
    - USDA soil textural class with rock fragment modifiers
    - Soil structure, grade size and shape
    - Soil consistence, root abundance and size
    - Soil boundary
    - Occurrence of saturated soil, impermeable layers/lenses, groundwater, bedrock or disturbed soil
- ► It is HIGHLY RECOMMENDED that the field verification be conducted by a qualified geotechnical professional.

Step 4. Compute runoff control volumes.

Calculate the volume control standard (VCS). Details on the Stormwater Sizing Criteria are found in Chapter 7.

Step 5. Size Practice and Determine Bioretention Type (Note: Steps 5, 6, 7 and 8 are iterative)

After following the steps outlined above, the designer will presumably know the location of naturally occurring permeable soils, the depth to the water table, bedrock or other impermeable layers, and the contributing drainage area. While the first step in sizing a bioretention practice is selecting the type of design variant for the site, the basic design procedures for each type of bioretention practice are similar.

a. Volume control standard (VCS) – After determining the volume control standard for the entire site (Step 1), determine the portion of the total volume that will be treated by the bioretention facility.

b. Based on the known VCS, infiltration rates of the underlying soils and the known existing potential pollutant loading from proposed/existing landuse select the appropriate bioretention practice from Table 8.5. Note: the determination for under-drain is an iterative sizing process.

Table 8.23 Summary of Bioretention Variants for Permeability of Native Soils and Potential Landuse Pollutant Loading

Bioretention Type	Variant	Underlying Soil Performance Criteria
Infiltration/Recharge Facility	No under-drain	Higher recharge potential (facility drain time without under-drain is < 72 hours, 48 hours if used to meet MPCA reqs.)
Filtration/Partial Recharge Facility	Under-drain	Lower recharge potential (facility drain time without under-drain is < 72 hours, 48 hours if used to meet MPCA reqs.)
Infiltration/Filtration/Recharge Facility	Elevated under-drain	Higher nutrient loadings and/or quantity control
Filtration Only Facility	Under-drain with liner	Hot Spot Treatment

Information collected during the Physical Suitability Evaluation (see Step 2) should be used to explore the potential for multiple bioretention practices versus relying on a single bioretention facility. Bioretention is best employed close to the source of runoff generation and is often located in the upstream portion of the stormwater treatment train, with additional stormwater BMP's following downstream.

Infiltration Rates – If the infiltration rate is not measured, the following table provides infiltration rates for the design of infiltration practices. These infiltration rates represent the long-term infiltration capacity of a practice and are not meant to exhibit the capacity of the soils in the natural state. Select the design infiltration rate from the table based on the least permeable soil horizon within the first five feet below the bottom elevation of the proposed infiltration practice.

The infiltration capacity and existing hydrologic regime of natural basins are inheritably different than constructed practices and may not meet Inver Grove Heights permit requirements for constructed practices. In the event that a natural depression is being proposed to be used as an infiltration system, the design engineer must demonstrate the following information: infiltration capacity of the system under existing conditions (inches/hour), existing drawdown time for the high water level (HWL) and a natural overflow elevation. The design engineer should

also demonstrate that operation of the natural depression under post-development conditions mimics the hydrology of the system under pre-development conditions.

Table 8.24. Design Infiltration Rates

Hydrologic Soil Group	Infiltration Rate [inches/hour]	Soil Textures	Corresponding Unified Soil Classification
A	1.6	Gravel, sandy gravel and silty gravels	**GW** - Well-graded gravels, sandy gravels **GP** – Gap-graded or uniform gravels, sandy gravels **GM** - Silty gravels, silty sandy gravels **SW** - Well-graded, gravelly sands
	0.8	Sand, loamy sand or sandy loam	**SP** - Gap-graded or uniform sands, gravelly sands
B	0.6	Silt loam	**SM** - Silty sands, silty gravelly sands
	0.3	Loam	**MH** – Micaceous silts, diatomaceous silts, volcanic ash
C	0.2	Sandy clay loam	**ML** - Silts, very fine sands, silty or clayey fine sands
D	< 0.2	Clay loam, silty clay loam, sandy clay, silty clay or clay	**GC** – Clayey gravels, clayey sandy gravels **SC** – Clayey sands, clayey gravelly sands **CL** – Low plasticity clays, sandy or silty clays **OL** – Organic silts and clays of low plasticity **CH** – Highly plastic clays and sandy clays **OH** – Organic silts and clays of high plasticity

Source: Thirty guidance manuals and many other stormwater references were reviewed to compile recommended infiltration rates. All of these sources use the following studies as the basis for their recommended infiltration rates: (1) Rawls, Brakensiek and Saxton (1982); (2) Rawls, Gimenez and Grossman (1998); (3) Bouwer and Rice (1984); and (4) Urban Hydrology for Small Watersheds (NRCS). The rates presented in this infiltration table use the information compiled from these sources as well as eight years of infiltration rates collected in various infiltration practices located in the South Washington Watershed District.

If the infiltration rates are measured the tests shall be conducted at the proposed bottom elevation of the infiltration practice. If the infiltration rate is measured with a double-ring infiltrometer the requirements of ASTM D3385 shall be used for the field test.

c. Area sizing for facilities with and without an under drain:

Without An Under Drain

The bioretention surface area is computed using the following equation, for those practices that are designed **without an under drain**:

$$A_f = (VCS \times d_f) / [i \times (h_f + d_f) \times t_f]$$

Where:

A_f = surface area of filter bed (ft^2)

d_f = filter bed depth (ft)
i = infiltration rate of underlying soils (ft/day)
h_f = average height of water above filter bed (ft)
t_f = design filter bed drain time (days)
(2 days is the recommended maximum t_f for bioretention)

Use Table 8.19 to determine the infiltration rate of the underlying soils. Note that these numbers are intentionally conservative based on experience gained from Minnesota infiltrations sites.

With An Under Drain
The bioretention surface area is computed using the following equation, for those practices that are designed **with an under drain**:

$$A_f = (VCS \times d_f) / [k \times (h_f + d_f) \times t_f]$$

Where:
A_f = surface area of filter bed (ft^2)
d_f = filter bed depth (ft)
k = coefficient of permeability of filter media (ft/day)
h_f = average height of water above filter bed (ft)
t_f = design filter bed drain time (days)
(2 days is the recommended maximum t_f for bioretention)

The following coefficients of permeability should be used for the Planting Medium / Filter Media Soil:

0.5 ft/day (Clayton and Schueler, 1996) (Note: value is conservative to account for clogging associated with accumulated sediment)

Step 6. Size outlet structure and/or flow diversion structure, if needed (Note: Steps 5, 6, 7 and 8 are iterative)

It is REQUIRED that a secondary outlet be incorporated into the design of a bioretention practice to safely convey excess stormwater.

Step 7. Check volume, peak discharge rates and period of inundation against State, local and Watershed Management Organization requirements (Note: Steps 5, 6, 7 and 8 are iterative)

Follow the design procedures identified in the Stormwater System Sizing Criteria section of the Manual (Chapter 7) to determine the volume control.

Model the proposed development scenario using a surface water model appropriate for the hydrologic and hydraulic design considerations specific to the site (see also Chapter 9 of the manual). This includes defining the parameters of the bioretention practice defined above: sedimentation basin elevation and area (defines the pond volume), infiltration/permeability rate, and outlet structure and/or flow diversion information. The results of this analysis can be used to determine whether or not the proposed design meets the applicable requirements. If not, the design will have to be re-evaluated (back to Step 5).

Peak Discharge Rates

Outflow must be limited such that erosion does not occur down gradient of the bioretention practice.

Period of Inundation

Bioretention practices shall discharge through the soil or filter media in 72 hours or less (48 hours if its being used to meet MPCA permit requirements). Additional flows that cannot be infiltrated or filtered in 72 hours should be routed to bypass the system through a stabilized discharge point. This criterion was established to provide the following: wet-dry cycling between rainfall events; unsuitable mosquito breeding habitat; suitable habitat for vegetation; aerobic conditions; and storage for back-to-back precipitation events.

Other design requirements may apply to a particular site. The applicant should confirm local design criteria and applicability (see Step 3).

Step 8. Perform groundwater mounding analysis (Note: Steps 5, 6, 7 and 8 are iterative)

Ground water mounding, the process by which a mound forms on the water table as a result of recharge at the surface, can be a limiting factor in the design and performance of bioretention practices where infiltration is a major design component. A minimum of 3 feet of separation between the bottom of the bioretention practice and the seasonally high water table is REQUIRED (5 feet HIGHLY RECOMMENDED) to maintain the hydraulic capacity of the practice and provide adequate water quality treatment.

The most widely known and accepted analytical methods to solve for ground water mounding are based on the work by Hantush (1967) and Glover (1960). The maximum ground water mounding potential should be determined through the use of available analytical and numerical methods. Detailed ground water mounding analysis should be conducted by a trained hydrogeologist or equivalent as part of the site design procedure.

Step 9. Determine pretreatment volume and design pretreatment measures

Some form of dry or wet pretreatment is REQUIRED prior to the discharge of stormwater into the bioretention practice, to remove any sediment and fines that may result in clogging of the soils in the sediment basin area. If a grass filter strip is used, it is HIGHLY RECOMMENDED that it be sized using the guidelines in Table 8.20.

Table 8.25 Guidelines for Filter Strip Pretreatment Sizing

Parameter	Impervious Parking Lots				Residential Lawns			
Maximum Inflow Approach Length (ft.)	35		75		75		150	
Filter Strip Slope	≤2%	>2%	≤2%	>2%	≤2%	>2%	≤2%	>2%
Filter Strip Minimum Length	10’	15’	20’	25’	10’	12’	15’	18’

Grass channel sizing

It is HIGHLY RECOMMENDED that grass channel pretreatment for bioretention be a minimum of 20 feet in length and be designed according to the following guidelines:

- Parabolic or trapezoidal cross-section with bottom widths between 2 and 8 feet
- Channel side slopes no steeper than 3:1 (horizontal:vertical).
- Flow velocities limited to 1 foot per second or less for peak flow associated with the water quality event storm (i.e., 0.5 or 1.0 inches depending on watershed designation).
- Flow depth of 4 inches or less for peak flow associated with the water quality event storm.

Step 10. Prepare Vegetation and Landscaping Plan
See Major Design Elements for guidance on preparing vegetation and landscaping management plan.

Step 11. Prepare Operations and Maintenance (O&M) Plan
See Operations and Maintenance for guidance on preparing an O&M plan.

F. Links to other Manuals

Price George's County Programs & Planning Division Department of Environmental Resources. 2002. *Bioretention Manual*. Landover, MD.

G. References

Davis, A.P., M. Shokouhian, H. Sharma and C. Minani. 1998. Optimization of *Bioretention for Design for Water Quality and Hydrologic Characteristics.* n.p.

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http://www.vtwaterquality.org/stormwater.htm.

Winer, R. 2000. National Pollutant Removal Performance Database.

Wisconsin DNR Bioretention for Infiltration Conservation Practice Standard 1004. 2004.
http://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm#Post.

INFILTRATION PRACTICES

Lino Lakes City Hall - Infiltration trench
Lino Lakes, MN

Bradshaw Celebration of Life Center - underground storage & infiltration
Stillwater, MN

Definition:
Natural or constructed depressions located in permeable soils that capture, store and infiltrate the volume of stormwater runoff associated with a particular design event.

KEY CONSIDERATIONS

Design Criteria:
- Contributing drainage area
- Underlying soil types
- Depth to the water table, bedrock or other impeding layer
- Proximity to buildings, drinking water supplies, Karst features, etc.
- Source of stormwater runoff

Benefits:
- Reduces volume of stormwater runoff
- Increases ground water recharge
- Improves surface water quality
- Provides thermal benefits (e.g. to cold water fisheries)
- Mimics pre-development hydrology

Limitations:
- Unusual construction considerations
- Potential for ground water contamination
- Tendency to lose effectiveness over time due to clogging – if not properly constructed or maintained
- Not recommended for areas with steep slopes
- May require landscaping: consideration should be given to periods oF inundation and drought

MANAGEMENT SUITABILITY

X	Volume Control
X	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
X	Wetland Bounce

MECHANISMS

X	Infiltration
X	Screening/ Filtration
X	Temperature Control
	Settling
	Evaporation
X*	Transpiration *if vegetated
X	Soil Adsorption
X	Biological/ Micro. Uptake

POLLUTION REMOVAL

95%	Total Suspended Solids
65%/ 50%	Nutrients - Total Phosphorus/ Total Nitrogen
95%	Metals - Cadmium, Copper, Lead, and Zinc
NA	Pathogens - Coliform, Streptococci, E. Coli
NA	Toxins - Chloride, Hydrocarbon, Pesticide

SITE FACTORS

1/ 5/ 50 AC Max	Drainage Areas: Dry Well/ Trench/ Basin
20%	Max. Site Slope
3'	Min. Depth to Bedrock
3'	Min. Depth to Seasonally High Water Table
A,B,C*,& D*	NRCS Soil Type *C & D soils have limited infiltration ability but can be used to match pre-development conditions
Poor - Good	Freeze/ Thaw Suitability

Description:
In general terms, infiltration systems can be described as natural or constructed depressions located in permeable soils that capture, store and infiltrate stormwater runoff within 72 hours (48 hours if they're being used to meet MPCA permit requirements). These depressions can be located at the surface of the ground (e.g. infiltration basin) or they can be designed as underground facilities (e.g. structural chamber or excavated pit filled with aggregate such as an infiltration trench). Typically, infiltration systems are designed with one or more pre-treatment facilities or they are designed as off-line facilities.

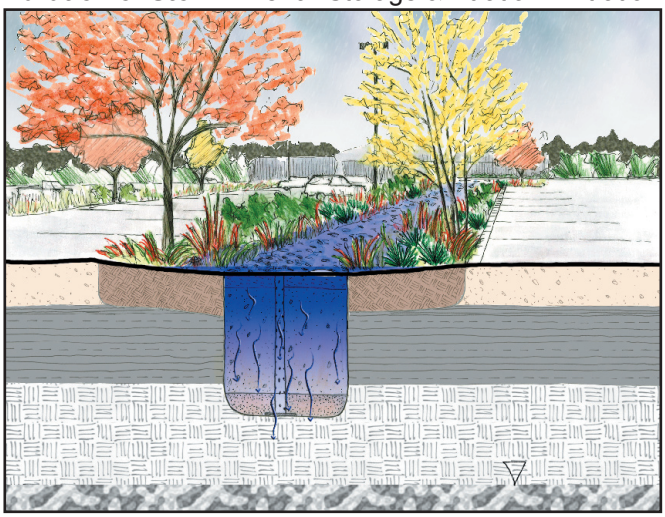
Infiltration systems should be located in permeable soils and a minimum 3-foot distance is REQUIRED from the bottom of the practice to the seasonally high water table, bedrock or other impeding layer per the Minnesota Pollution Control Agency Construction General Permit (CGP). Dry wells and Trenches should be designed to handle the smaller, more frequent rainfall events. Stormwater associated with the larger rainfall events should bypass these practices by a separate pipe or an overflow device. Infiltration basins and underground infiltration systems should be designed to handle both the water quality volume and as the water quantity volume.

Infiltration systems can be designed to address a number of stormwater management issues including: water quality, stormwater runoff reduction, flow attenuation, thermal impacts to cold water fisheries, and ground water recharge.

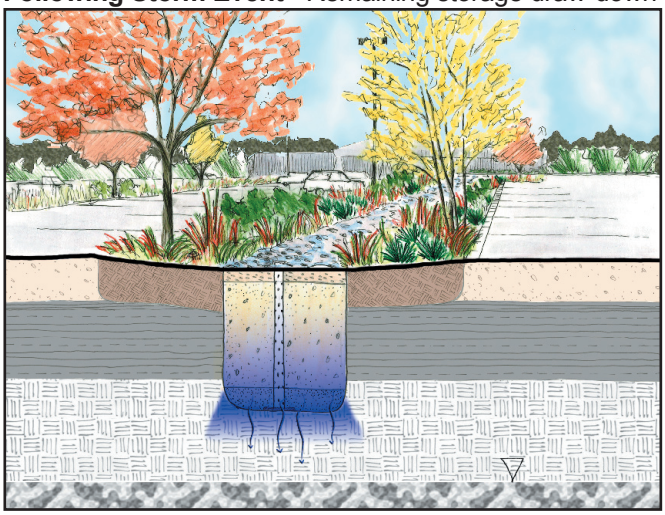
STORM SEQUENCE

Start of Storm Event - Initial runoff & storage

Duration of Storm Event - Storage & filtration/infiltration



Following Storm Event - Remaining storage draw-down



Courtesy of Rice Creek Watershed District

A. Suitability

General

Stormwater infiltration practices capture and temporarily store stormwater before allowing it to infiltrate into the soil. Design variants include; the infiltration basin, the infiltration trench, the dry well and the underground infiltration system. As the stormwater penetrates the underlying soil, chemical and physical adsorption processes remove pollutants and delay peak stormwater flows. Infiltration practices are applicable to sites with naturally permeable soils and a suitable distance to the seasonally high groundwater table, bedrock or other impermeable layer. They may be used in residential and other urban settings where elevated runoff volumes, pollutant loads, and runoff temperatures are a concern. In applications where the stormwater runoff has a particularly high pollutant load or where the soils have very high infiltration rates, a significant amount of pretreatment should be provided to protect the groundwater quality.

Function Within Stormwater Treatment Train

Infiltration practices may be located at the end of the treatment train or they can be designed as off-line configurations where the volume control standard volume is diverted to the infiltration practice. In any case, the practice may be applied as part of a stormwater management system to achieve one of the following objectives:

- reduce stormwater pollutants
- increase groundwater recharge
- decrease runoff peak flow rates
- decrease the volume of stormwater runoff
- preserve base flow in streams
- reduce thermal impacts of runoff

Inver Grove Heights Permit Applicability

One of the goals of this manual is to facilitate an understanding of and compliance with the city of Inver Grove Heights' Volume Control Standard (VCS). This standard must be met on all new and re-development projects taking place in the northwest area.

Infiltration systems may reduce the 5-year 24-hour infiltration standard by the amount that the practice is able to store and infiltrate. Infiltration areas are expected to make up a large portion of the 5-year 24-hour volume control standard.

The following terms are thus used in the text to distinguish various levels of green roof design guidance:

REQUIRED:	Indicates design standards stipulated by the IGH PUD.
HIGHLY RECOMMENDED:	Indicates design guidance that is extremely beneficial or necessary for proper functioning of the practice, but is not specifically required by the City of Inver Grove Heights.
RECOMMENDED:	Indicates design guidance that is helpful for performance but not critical to the design.

Design Variants

- ***Infiltration Basin*** – An infiltration basin is a natural or constructed impoundment that captures, temporarily stores and infiltrates the design volume of water over several days. In the case of a constructed basin, the impoundment is created by excavation or embankment. Infiltration basins are commonly used for drainage areas of 5 to 50 acres with land slopes that are less than 20 percent. Typical depths range from 2 to 12 feet, including bounce in the basin.
- ***Infiltration Trench (a.k.a. infiltration gallery)*** – An infiltration trench is a shallow excavated trench, typically 3 to 12 feet deep, that is backfilled with a coarse stone aggregate allowing for the temporary storage of runoff in the void space of the material. Discharge of this stored runoff occurs through infiltration into the surrounding naturally permeable soil. Trenches are commonly used for drainage areas less than 5 acres in size.
- ***Dry Wells (a.k.a. infiltration tubes, french drains, soak-away pits or soak holes)*** – A dry well or soak away pit is a smaller variation of an infiltration trench. It is a subsurface storage facility (a structural chamber or an excavated pit backfilled with a coarse stone aggregate) that receives and temporarily stores stormwater runoff. Discharge of this stored runoff occurs through infiltration into the surrounding naturally permeable soil. Due to their size, dry wells are typically designed to handle stormwater runoff from smaller drainage areas, less than one acre in size (e.g. roof tops).
- ***Underground Infiltration Systems*** – Several underground infiltration systems, including pre-manufactured pipes, vaults, and modular structures, have been developed as alternatives to infiltration basins and trenches for space-limited sites and stormwater retrofit applications. These systems are similar to infiltration basins and trenches in that they are designed to capture, temporarily store and infiltrate the design volume of stormwater over several days. Underground infiltration systems are generally applicable to small development sites (typically less than 10 acres) and should be installed in areas that are easily accessible to routine and non-routine maintenance. These systems should not be located in areas or below structures that cannot be excavated in the event that the system needs to be replaced.

Note: There is some concern that underground infiltration systems and dry wells meet the U.S. Environmental Protection Agency (EPA) definition of a Class V injection well. Class V injection wells are defined as any bored, drilled, or driven shaft, or dug hole that is deeper than its widest surface dimension, or an improved sinkhole, or a subsurface fluid distribution system (U.S. Environmental Protection Agency, When are Storm Water Discharges Regulated as Class V Well, June 2003).

Retrofit Suitability

The narrow and versatile shape of infiltration trenches and dry wells makes them well suited for retrofit projects. For example, infiltration practices can be situated along the margin or perimeter of a developed site or roadway in many cases. They are particularly desirable as retrofit practices in watersheds or catchments that are targeting volume reduction practices to help minimize channel erosion. Caution should be used when implementing infiltration practices for treatment of runoff from industrial areas with exposed significant materials or from vehicle fueling and maintenance areas. Generally, infiltration should not be used to treat runoff from manufacturing or industrial sites or other areas with high pollutant concentrations unless correspondingly high levels of pretreatment are provided. Pre-approval from City staff should be obtained in the early planning stages.

Cold Climate Suitability

Various options for use of infiltration are available for treating snowmelt runoff. Some of the installations are built below the frost line (trenches, sub-grade proprietary chambers) and do not need further adaptation for the cold. However, some special consideration is HIGHLY RECOMMENDED for surface systems.

The problem with infiltration in cold weather is the ice that forms both over the top of the facility and within the soil interstices. To avoid these problems to the extent possible, it is HIGHLY RECOMMENDED that the facility be actively managed to keep it dry before it freezes in the late fall. This can be done by various methods, including limiting inflow, under-drainage, and surface disking.

Even if the infiltration properties of an infiltration practice are marginal for snowmelt runoff, the storage available in the facility will provide some storage if it is dry entering the melt season. Routing the first high-soluble portions of snowmelt to an infiltration facility provides the opportunity for soil treatment (filtration, adsorption, microbial activity) of these solubles. Again, however, flow originating in an industrial area, a high traffic area where large amounts of salt are added, or another PSH should be diverted away from infiltration systems.

Proprietary, sub-grade infiltration systems provide an alternative to standard surface based systems. Essentially, these systems provide an insulated location for **pre-treated** snowmelt to be stored and slowly infiltrated, or simply filtered and drained away if groundwater sensitivity is an issue. The insulating value of these systems adds to their appeal as low-land-consumption alternatives to ponds and surface infiltration basins.

Water Quantity Treatment

The amount of stormwater volume infiltrated depends on the design variant selected. Smaller infiltration practices (e.g. infiltration trenches) should either be designed off-line using a flow diversion, or designed to safely pass large storm flows while still protecting the infiltration area. In many cases in Inver Grove Heights (e.g. extremely permeable soils), these smaller infiltration practices can accommodate the volume control standard (VCS)

Due to their size, the larger infiltration practices (e.g. infiltration basins and underground infiltration systems) have the potential to provide greater water quantity benefits due to their size. Surcharge storage above the practice bottom is available for detention. Outlet structures can be sized to partially or fully accommodate larger storm peak discharge control while allowing the volume below the outlet to infiltrate.

Water Quality Treatment

Infiltration practices can remove a wide variety of stormwater pollutants through chemical and bacterial degradation, sorption, and filtering. Surface water load reductions are also realized by virtue of the reduction in runoff volume. Due to the logistical challenges presented in structuring a study design, the number of scientific studies documenting the pollutant removal capability of infiltration practices is limited. However, pollutant removal and effluent concentration data for select parameters are provided in Tables 8.26 and 8.27, respectively.

Table 8.26. Percent Removal of Key Pollutants by Infiltration Practices (Winer, 2000)

Practice	TSS [%]	Total Phosphorus [%]	Total Nitrogen [%]	Metals[1] [%]	Bacteria [%]	Hydro-carbons [%]
Infiltration Practices[3]	95	80	50	95[2]	ND	ND

Notes
1. Average of zinc and copper. Only zinc for infiltration
2. Based on fewer than five data points (i.e., independent monitoring studies)
3. Includes porous pavement, which is not on the list of approved practices.

ND: No Data

Source: Winer, 2000

Table 8.27. Typical BMP Effluent Concentrations (Winer, 2000)

Practice Group	TSS	TP	TN	Cu[1]	Zn[1]
Infiltration Practices[2]	17	0.05	3.8	4.8	39

1. Units for Zn and Cu are micrograms per liter
2. Data based on fewer than five data points

Source: Winer, 2000

Limitations

The following general limitations should be recognized when considering installation of infiltration practices:

- Limited monitoring data are available and field longevity is not well documented
- Failure can occur due to improper siting, design, construction and maintenance
- Systems are susceptible to clogging by sediment and organic debris
- There is a risk of groundwater contamination depending on subsurface conditions, land use and aquifer susceptibility
- They are not ideal for stormwater runoff from land uses or activities with the potential for high sediment or pollutant loads
- Not recommended for areas with steep slopes.

B. Major Design Elements

Physical Feasibility Initial Check

- ***Drainage Area*** – It is HIGHLY RECOMMENDED that the following infiltration practices be designed with the indicated maximum drainage areas:
    - Dry well – 1 acre
    - Infiltration Trench – 5 acres
    - Underground Infiltration System – 10 acres
    - Infiltration Basin – between 5 and 50 acres.

- ***Site Topography and Slopes*** – Unless slope stability calculations demonstrate otherwise, it is HIGHLY RECOMMENDED that infiltration practices be located a minimum horizontal distance of 200 feet from

down gradient slopes greater than 20%, and that slopes in contributing drainage areas be limited to 15%.

- ***Soils*** – It is HIGHLY RECOMMENDED that native soils in proposed infiltration areas have a minimum infiltration rate of 0.2 inches per hour (typically Hydrologic Soil Group A, B and C soils). Initially, soil infiltration rates can be estimated from NRCS soil data, and confirmed with an on-site infiltration evaluation or geotechnical investigation (see step 3 under Design Procedures). It is HIGHLY RECOMMENDED that native soils have silt/clay contents less than 40% and clay content less than 20%, and that infiltration practices not be situated in fill soils.
- ***Depth to Ground Water Table and Bedrock*** – It is REQUIRED that infiltration practices be designed with a minimum vertical distance of 3 feet between the bottom of the infiltration practice and the seasonally high water table or bedrock layer (see also Step 8 under the Design Procedure section). Local authorities may require greater separation depths.
- ***Site Location / Minimum Setbacks*** – It is HIGHLY RECOMMENDED that infiltration practices not be hydraulically connected to structure foundations or pavement, to avoid seepage and frost heave concerns, respectively. If groundwater contamination is a concern, it is RECOMMENDED that groundwater mapping be conducted to determine possible connections to adjacent groundwater wells. The following minimum setbacks are REQUIRED by the Minnesota Department of Health for the design and location of infiltration practices. It will be necessary to consult local ordinances for further guidance on siting infiltration practices.

Table 8.28. Minimum setback requirements (Minnesota Department of Health).

Setback from	Minimum Distance [feet]
Property Line	10
Building Foundation*	10
Private Well	50
Public Water Supply Well	50
Septic System Tank/Leach Field	35
* Minimum with slopes directed away from the building.	

Source: Minnesota Department of Health

Conveyance

It is HIGHLY RECOMMENDED that a flow splitter or diversion structure be provided to divert the VCS to the infiltration practice and allow larger flows to bypass the practice, unless the infiltration practice is sized to retain larger storms. Where a flow splitter is not used, it is HIGHLY RECOMMENDED that contributing drainage areas be limited to the appropriate size given the BMP and an overflow be provided within the practice. It is also HIGHLY RECOMMENDED that the designer evaluate the potential for erosion to downstream of infiltration facilities.

Pretreatment

- It is REQUIRED that some form of pretreatment, such as a sand filter, filter strip, sedimentation basin, grass channel, or a combination of these practices be installed upstream of the infiltration practice. Pretreatment standards for infiltration practices in Inver Grove Heights state that the VCS must be treated to 85%. The developer has the responsibility to show how this will be accomplished and it must be approved by the city engineer. More information on pretreatment is available in Chapter 7.

Treatment

- ***Space Occupied*** – Varies depending on the depth of the practice. Typically, infiltration trenches are three to twelve feet deep with a width less than 25 feet. A dry well is essentially a smaller version of an infiltration trench, consistent with the fact that the drainage area to an infiltration trench is typically five times greater (or larger) than that of a dry well. Underground infiltration systems are larger practices that range in depth from approximately 2 to 12 feet. The surface area of all infiltration practices is a function of the 72-hour drawdown requirement (48-hour drawdown if its being used to meet MPCA permit requirements) and the infiltration capacity of the underlying soils.
- ***Practice Slope*** – It is RECOMMENDED that the bottom of all infiltration practices be flat, in order to enable even distribution and infiltration of stormwater. It is RECOMMENDED that the longitudinal slope range only from the ideal 0% up to 1%, and that lateral slopes be held at 0%.
- ***Side Slopes*** – It is HIGHLY RECOMMENDED that the maximum side slopes for an infiltration practice be 3:1 (h:v).
- ***Depth*** – The depth of an infiltration practice is a function of the maximum drawdown time and the design infiltration rate. The REQUIRED drawdown time for infiltration practices is 72 hours or less (48 hours or less if used to meet MPCA permit requirements) and so the depth of the practice should be determined accordingly.
- ***Groundwater Protection*** – It is REQUIRED that runoff from potential stormwater hotspots (PSHs) not be infiltrated unless adequate pretreatment has been provided and pre-approval from City staff is obtained.
- ***Aesthetics*** – Infiltration basins can be effectively integrated into the site planning process, and aesthetically designed as attractive green spaces planted with native vegetation. Infiltration trenches are less conducive to site aesthetics, but the surface of trenches can be designed with turf cover crops if desired.

Landscaping

- It is REQUIRED that impervious area construction be completed and pervious areas established with dense and healthy vegetation prior to introduction of stormwater into an infiltration practice.
- It is RECOMMENDED that vegetation associated with infiltration practices be established to blend into the surrounding area, that native species be used wherever possible. It is HIGHLY RECOMMENDED that deep rooted plants such as prairie grass be used, because they increase the infiltration capacity of the underlying soils. Dry wells and infiltration trenches can be covered with permeable topsoil and planted with grass to match the surrounding landscape.
- Due to soil compaction concerns, it is HIGHLY RECOMMENDED that infiltration areas not be used for recreational purposes.
- It is HIGHLY RECOMMENDED that vegetation associated with infiltration practices be regularly maintained and bare areas seeded. Mowing practices can be used to maintain native vegetation.
- It is RECOMMENDED that soil testing be conducted in infiltration practices, to determine if fertilizer application is warranted. Incorporating mulch or compost into the soil or planting with salt tolerant grasses can counter soil fertility problems caused by high chloride concentrations.

Safety

- Dry wells, infiltration trenches and subsurface infiltration systems do not pose any major safety hazards. Infiltration basins should have similar side slope considerations as ponds and wetlands.
- If a dry well or infiltration trench is greater than five feet deep, it is REQUIRED that OSHA health and safety guidelines be followed for safe construction practices. Additional information on safety for construction sites is available from OSHA. Use the following link to research safety measures for excavation sites: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10930
- When riser pipe outlets are used in infiltration basins, it is HIGHLY RECOMMENDED that be constructed with manholes that either have locks or are sufficiently heavy to prevent easy removal.
- Fencing of dry wells and infiltration trenches is neither necessary nor desirable. Infiltration basins may warrant fencing in some situations.

Construction Details

CADD based details for infiltration systems are contained in Appendix A. The following details, with specifications, have been created for infiltration systems:

- Infiltration Basin
- Infiltration Trench
- Subsurface Infiltration System
- Inlet/Outlet Structures

C. Construction Specifications

Given that the construction of infiltration practices incorporates techniques or steps which may be considered non-standard, it is RECOMMENDED that the construction specifications include the following format and information.

I. Temporary Erosion Control
- Installation prior to site disturbance
- Catch basin/inlet protection
- Use of BMP as temporary sedimentation basin

II. Excavation, Backfill and Grading
- Timing of grading of infiltration practices (relative to total site development)
- Use of low-impact, earth moving equipment
- Do not over-excavate
- Restoration in the event of sediment accumulation during construction of practice
- Gravel backfill specifications
- Gravel filter specifications
- Filter fabric specifications
- Observation well specifications

III. Native Plants, Planting and Transplanting (MN Plant List in Appendix B of the Manual)
- Site preparation of planting areas
- Timing of native seeding and native planting
- Weed control
- Watering of plant material

IV. Construction Sequence Scheduling
- Temporary construction access
- Location of silt fence installation to protect BMPs and downgradient receiving waters
- Removal and storage of excavated material
- Installation of underground utilities
- Rough grading
- Seeding and mulching disturbed areas
- Road construction
- Final grading
- Site stabilization
- Installation of semi-permanent and permanent erosion control measures
- Silt fence removal

V. Construction Observation
- Adherence to construction documents
- Verification of physical site conditions
- Erosion control measures installed appropriately

D. Operation and Maintenance

Overview

Effective long-term performance of infiltration practices requires an infiltration management plan (REQUIRED), performance monitoring (HIGHLY RECOMMENDED), and a dedicated and routine maintenance schedule with clear guidelines and schedules (REQUIRED).

The infiltration management plan (operation plan) should address the following items: periods of inundation, wet/dry cycling of soils, operating instructions for drawdown valves, gates and removable weirs.

The monitoring plan should address the following items: Inspection and Efficiency Assessment, water quality monitoring, monitoring of groundwater elevations, long-term infiltration capacity and plant tolerances.

Elements to be considered for the development of a maintenance plan are broken into the following categories: Design Phase Maintenance Considerations; Construction Phase Maintenance Considerations; and Post-Construction Maintenance Considerations. In general terms, the most frequently cited maintenance concern for infiltration practices is clogging caused by organic matter and fine silts. Common operational problems include:

- Clogging and sediment deposition
- Erosion of contributing land or in channels leading to the practice
- Maintaining appropriate surface vegetation

Table 8.29 provides a summary of common problems for infiltration trenches and basins.

Table 8.29 Typical Maintenance Problems for Infiltration Trenches and Basins

Problem	Practices Applied To	Comments
Clogging, sediment deposition	Both	Key issue for infiltration practice. Requires vigilant inspection and maintenance.
Surface Vegetation	Both	Often important to maintain vigorous growth at the base of infiltration practices (basins). Important to restrict woody vegetation from the surface of infiltration trenches.
Erosion of contributing land or in channels leading to practice	Both	In these practices, it is important to monitor not only the practice itself, but also upland infiltration to minimize the sediment load.
Damage to filter fabric	Trench	Infrequent but important maintenance concern.
Scouring at Inlet	Both	Similar issues to Ponds. Need to promote non-erosive flows that are evenly distributed
Access Issues	Both	Similar issues to Ponds. Need access for inspection and maintenance.
Concrete Failure	Basins, if they include a riser structure	Similar issues to ponds and wetlands.
Problems with the Embankment	Basins	Similar issues to dry ponds.

Design Phase Maintenance Considerations

Implicit in the design guidance in the previous sections is the fact that many design elements for infiltration systems can minimize the maintenance burden and maintain pollutant removal efficiency. Among them are:

- Providing easy access (typically 8 feet wide) to infiltration practices for routine maintenance is REQUIRED. Open lawn areas are RECOMMENDED locations for infiltration practices because of their accessibility.
- It is REQUIRED that a way to visually verify proper system operation be installed with each infiltration practice. It is REQUIRED that every dry well, infiltration trench and subsurface infiltration system design include an observation well consisting of an anchored six-inch diameter perforated PVC pipe fitted with a cap to facilitate periodic inspection and maintenance. It is also REQUIRED that infiltration basins include a draw down device that can be used for winter diversion and to conduct regular maintenance.
- It is HIGHLY RECOMMENDED that a mechanism such as a multi-stage outlet structure be incorporated into the design of the pretreatment and infiltration practices to facilitate draining for maintenance purposes.

Construction Phase Maintenance Considerations

Infiltration practices are particularly vulnerable during the construction phase for two reasons. First, if the construction sequence is not followed correctly, construction sediment can clog the practice. In addition, heavy construction can result in compaction of the soil, which can then reduce the soil's infiltration rate. For this reason, a careful construction sequence needs to be followed. Critical construction elements for infiltration practices are as follows:

- ***Avoid excessive compaction***
  It is REQUIRED that in order to prevent soil compaction, the proposed infiltration area be staked off and marked during construction to prevent heavy equipment and traffic from traveling over it. In addition, it is HIGHLY RECOMMENDED that the side walls of dry wells and infiltration trenches be roughened if they have been smeared by heavy equipment.
- ***Stabilize Vegetation Before and After Construction***
  Excessive sediment loadings can occur without the use of proper erosion and sediment control practices during the construction process. It is REQUIRED that upland drainage areas be properly stabilized with a thick layer of vegetation, particularly immediately following construction, to reduce sediment loads. If infiltration practices are in-place during construction activities, it is REQUIRED that sediment and runoff be kept away the infiltration area, such as with diversion berms and soil-stabilizing vegetation around the perimeter of the practice.
- ***Correctly Install Filter Fabrics***
  Large tree roots should be trimmed flush with the sides of dry wells and infiltration trenches to prevent puncturing or tearing of the filter fabric during subsequent installation procedures. When laying out the geotextile, the width should include sufficient material to compensate for perimeter irregularities in the dry well or trench and for a 6-inch minimum top overlap. The filter fabric itself should be tucked under the sand layer on the bottom of the dry well of infiltration trench, and stones or other anchoring objects should be placed on the fabric at the trench sides to keep the excavation open during windy periods. Voids may occur between the fabric and the excavated sides of the practice. Natural soils should be placed in any voids to ensure fabric conformity to the excavation sides.
- ***Carefully Finish Final Grading***
  Initial infiltration basin excavation should be carried to within 2 feet of the final elevation of the basin floor. It is REQUIRED that infiltration systems not be excavated to final grade until the contributing drainage area has been constructed and fully stabilized. The final phase excavation should remove all

accumulated sediment and be done by light tracked equipment to avoid compaction of the basin floor and provide a well-aerated, highly porous surface texture.

- ***Keep Infiltration Practices "Off-line" until Construction Is Complete***
  It is REQUIRED that sediment and runoff be kept completely away from the infiltration area during construction. Thus, infiltration practices should never serve as sediment control devices during site construction. It is HIGHLY RECOMMENDED that construction of infiltration practices be suspended during snowmelt or rainfall, in order to prevent soil smearing, clumping, or compaction.
- ***Establish Permanent Vegetation***
  Establishing dense vegetation on the basin side slopes is HIGHLY RECOMMENDED, to reduce erosion and sloughing and provide a natural means of maintaining relatively high infiltration rates. Vegetative cover at inflow points to the basin is also HIGHLY RECOMMENDED to provide erosion protection and reduce sediment accumulation. The use of native grasses is RECOMMENDED for seeding primarily due to their adaptability to local climates and soil conditions.

Inspections during construction are needed to ensure that the infiltration practice is built in accordance with the approved design and standards and specifications. Detailed inspection checklists should be used that include sign-offs by qualified individuals at critical stages of construction to ensure that the contractor's interpretation of the plan is acceptable to the designer. An example construction phase inspection checklist for both infiltration basins and infiltration trenches are provided in Appendix D.

Post-construction Operation and Maintenance

A maintenance plan clarifying maintenance responsibility is REQUIRED. Effective long-term operation of infiltration practices necessitates a dedicated and routine maintenance schedule with clear guidelines and schedules. Some important post-construction maintenance considerations are provided below. A more detailed checklist of maintenance activities and associated schedules is provided in Appendix D.

- A legally binding and enforceable maintenance agreement should be executed between the practice owner and the local review authority.
- Adequate access must be provided for all infiltration practices for inspection, maintenance, and landscaping upkeep, including appropriate equipment and vehicles.
- General infiltration trench maintenance activities and schedule are provided in Table 8.30.

Table 8.30 Typical Maintenance Activities for Infiltration Trenches

Activity	Schedule
► Replace pea gravel/topsoil and top surface filter fabric (when clogged).	As needed
► Ensure that contributing area, practice and inlets are clear of debris. ► Ensure that the contributing area is stabilized. ► Remove sediment and oil/grease from pretreatment devices, as well as overflow structures. ► Mow grass filter strips should be mowed as necessary. Remove grass clippings. ► Repair undercut and eroded areas at inflow and outflow structures	Monthly
► Check 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. ► Remove trees that start to grow in the vicinity of the trench.	Semi-annual Inspection

Table 8.30 Typical Maintenance Activities for Infiltration Trenches	
Activity	**Schedule**
► Disc or otherwise aerate basin bottom. De-thatch basin bottom.	Annually
► Scrape basin bottom and remove sediment. Restore original cross-section and infiltration rate. Seed or sod to restore ground cover.	Every 5 years
► Perform total rehabilitation of the trench to maintain design storage capacity. ► Excavate trench walls to expose clean soil.	Upon Failure

Source:EPA, 1999

Construction and Maintenance Costs

Table 8.31 lists the specific site components that are specific to infiltration practices. Not included in this table are those cost items that are common to all construction projects, such as mobilization, traffic control, erosion and sediment control, permitting, etc. A more detailed worksheet, utilizing 2005 construction prices, is contained in Appendix F.

Table 8.31 Infiltration Practices Cost Components			
Implementation Stage	**Primary Cost Components**	**Basic Cost Estimate**	**Other Considerations**
Site Preparation	Tree & plant protection	Protection Cost ($/acre) x Affected Area (acre)	Removal of existing structures, topsoil removal and stockpiling
	Infiltration area protection	Silt fence cost ($/'foot) x Perimeter of infiltration area	
	Clearing & grubbing	Clearing Cost ($/acre) x Affected Area (acre)	
	Topsoil salvage	Salvage Cost ($/acre) x Affected Area	
Site Formation	Excavation / grading	X-ft Depth Excavation Cost ($/acre) x Area (acre)	Soil & rock fill material, tunneling
	Hauling material offsite	Excavation Cost x (% of Material to be hauled away)	

Table 8.31 Infiltration Practices Cost Components			
Implementation Stage	**Primary Cost Components**	**Basic Cost Estimate**	**Other Considerations**
Structural Components	Vault structure (for underground infiltration)	($/structure)	Pipes, catchbasins, manholes, valves, vaults
	Media (for infiltration trenches)	Media cost ($/cubic yard) x filter volume (cubic yard)	
	Geotextile	Geotextile cost ($/cy) x area of trench, including walls	
	Inlet structure	($/structure)	
	Overflow structure	($/structure)	
	Observation well	($/structure)	
	Filter strip	Sod cost ($/square foot) x filter strip area	
Site Restoration	Soil preparation	Topsoil or amendment cost ($/acre) x Area (acre)	Tree protection, soil amendments, seed bed preparation, trails
	Seeding	Seeding Cost ($/acre) x Seeded Area (acre)	
	Planting / transplanting	Planting Cost ($/acre) x Planted Area (acre)	
Annual Operation, Maintenance, and Inspection	Sediment removal	Removal Cost ($/acre) x Area (acre) x Frequency (1x / 5yr)	Vegetation maintenance, cleaning of structures
	Debris removal	Removal Cost ($/acre) x Area (acre) x Frequency (2x / 1yr)	
	Inspection	Inspection Cost ($) x Inspection Frequency (6x / 1 yr)	
	Mowing (for some vegetative filters)	Mowing Cost ($) x Mowing Frequency (6x / 1 yr)	

E. Design Procedure

The following steps outline a recommended design procedure for infiltration practices in compliance with the Inver Grove Heights Stormwater Permit. Design recommendations beyond those specifically required by the permit are also included and marked accordingly.

Design Steps

<u>Step 1. Make a preliminary judgment as to whether site conditions are appropriate for the use of an infiltration practice, and identify the function of the practice in the overall treatment system</u>

A. Consider basic issues for initial suitability screening

- Site drainage area

- ► Site topography and slopes greater than 20%
- ► Soil infiltration capacity
- ► Regional or local depth to groundwater and bedrock
- ► Site Location/Minimum setbacks
- ► Presence of active Karst

B. Determine how the infiltration practice will fit into the overall stormwater treatment system

- ► Decide whether the infiltration practice is the only BMP to be employed, or if are there other BMPs addressing some of the treatment requirements.
- ► Decide where on the site the infiltration practice is most likely to be located.

Step 2. Confirm design criteria and applicability.

A. Check with local officials, WMOs, and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.
B. Determine whether the infiltration practice must comply with the MPCA Permit.

Step 3. Perform field verification of site suitability

- ► If the initial evaluation indicates that an infiltration practice would be a good BMP for the site, it is HIGHLY RECOMMENDED that a minimum of three **soil borings or pits** be dug (in the same location as the proposed infiltration practice) to verify soil types and infiltration capacity characteristics and to determine the depth to groundwater and bedrock.
- ► It is HIGHLY RECOMMENDED that the minimum depth of the soil borings or pits be five feet below the bottom elevation of the proposed infiltration practice.
- ► It is HIGHLY RECOMMENDED that soil profile descriptions be recorded and include the following information for each soil horizon or layer (Source: Site Evaluation for Stormwater Infiltration, Wisconsin Department of Natural Resources Conservation Practice Standards 2004):
    - Thickness, in inches or decimal feet
    - Munsell soil color notation
    - Soil mottle or redoximorphic feature color, abundance, size and contrast
    - USDA soil textural class with rock fragment modifiers
    - Soil structure, grade size and shape
    - Soil consistence, root abundance and size
    - Soil boundary
    - Occurrence of saturated soil, impermeable layers/lenses, groundwater, bedrock or disturbed soil
- ► It is HIGHLY RECOMMENDED that the field verification be conducted by a qualified geotechnical professional.

Step 4. Compute runoff control volumes.

Calculate the volume control standard (VCS). Details on the Unified Stormwater Sizing Criteria are found in Chapter 7.

If the infiltration practice is being designed to meet the requirements of the Inver Grove Heights Permit, the REQUIRED infiltration volume is the VCS. If part of the overall VCS is to be infiltrated by other BMPs, subtract that portion from the VCS to determine the part of the VCS to be infiltrated by the infiltration practice.

Step 5. Select design variant based on Physical Suitability Evaluation

Once the Physical Suitability Evaluation is complete, it is HIGHLY RECOMMENDED that the designer apply the Better Site Design principles in sizing and locating the infiltration practice(s) on the development

site. Given the volume control standard and the drainage area, select the appropriate infiltration practice for the first iteration of the design process.

Table 8.32 Summary of Infiltration Practices for Given Drainage Areas.

Infiltration Practice	Drainage Area
Infiltration Basin	5 to 50 acres
Infiltration Trench	less than 5 acres
Dry Wells	less than one acre
Underground Infiltration Systems	less than 10 acres

Note: Information collected during the site suitability evaluation (see Steps 1 and 3) should be used to explore the potential for multiple infiltration practices versus relying on a single infiltration facility. The use of smaller infiltration practices dispersed around a development is usually more sustainable than a single regional facility that is more likely to have maintenance and groundwater mounding problems (Source: Site Evaluation for Stormwater Infiltration, Wisconsin Department of Natural Resources Conservation Practice Standards 2004).

Step 6. Size infiltration practice (Note: Steps 5, 6, 7 and 8 are iterative)

After following the steps outlined above, the designer will presumably know the location of naturally occurring permeable soils, the depth to the water table, bedrock or other impermeable layer, and the contributing drainage area. While the first step in sizing an infiltration practice is selecting the type of infiltration practice for the site, the basic design procedures are very similar.

- ***Infiltration Location*** – Given the steps performed in the Physical Suitability Evaluation, identify the most suitable location for the infiltration practice. Pretreatment prior to infiltration is REQUIRED to remove total suspended solids and other pollutants associated with stormwater (see Step 9).
- ***Infiltration Rates*** – **If the infiltration rate is not measured**, the following table provides infiltration rates for the design of infiltration practices. These infiltration rates represent the long-term infiltration capacity of a practice and are not meant to exhibit the capacity of the soils in the natural state. Select the design infiltration rate from the table based on the least permeable soil horizon within the first five feet below the bottom elevation of the proposed infiltration practice.

Table 8.33 Design Infiltration Rates

Hydrologic Soil Group	Infiltration Rate [inches/ hour]	Soil Textures	Corresponding Unified Soil Classification
A	1.6	Gravel, sandy gravel and silty gravels	**GW** - Well-graded gravels, sandy gravels **GP** – Gap-graded or uniform gravels, sandy gravels **GM** - Silty gravels, silty sandy gravels **SW** - Well-graded, gravelly sands
	0.8	Sand, loamy sand or sandy loam	**SP** - Gap-graded or uniform sands, gravelly sands

Table 8.33 Design Infiltration Rates

Hydrologic Soil Group	Infiltration Rate [inches/ hour]	Soil Textures	Corresponding Unified Soil Classification
B	0.6	Silt loam	**SM** - Silty sands, silty gravelly sands
	0.3	Loam	**MH** – Micaceous silts, diatomaceous silts, volcanic ash
C	0.2	Sandy clay loam	**ML** - Silts, very fine sands, silty or clayey fine sands
D	< 0.2	Clay loam, silty clay loam, sandy clay, silty clay or clay	**GC** – Clayey gravels, clayey sandy gravels **SC** – Clayey sands, clayey gravelly sands **CL** – Low plasticity clays, sandy or silty clays **OL** – Organic silts and clays of low plasticity **CH** – Highly plastic clays and sandy clays **OH** – Organic silts and clays of high plasticity

Source: Thirty guidance manuals and many other stormwater references were reviewed to compile recommended infiltration rates. All of these sources use the following studies as the basis for their recommended infiltration rates: (1) Rawls, Brakensiek and Saxton (1982); (2) Rawls, Gimenez and Grossman (1998); (3) Bouwer and Rice (1984); and (4) Urban Hydrology for Small Watersheds (NRCS). SWWD, 2005, provides field documented data that supports the proposed infiltration rates.

The infiltration capacity and existing hydrologic regime of natural basins are inheritably different than constructed practices and may not meet the Permit requirements for constructed practices. In the event that a natural depression is being proposed to be used as an infiltration system, the design engineer must demonstrate the following information: infiltration capacity of the system under existing conditions (inches/hour), existing drawdown time for the high water level (HWL) and a natural overflow elevation. The design engineer should also demonstrate that operation of the natural depression under post-development conditions mimics the hydrology of the system under pre-development conditions.

If the infiltration rates are measured[1] the tests shall be conducted at the proposed bottom elevation of the infiltration practice. If the infiltration rate is measured with a double-ring infiltrometer the requirements of ASTM D3385 shall be used for the field test.

The measured infiltration rate shall be divided by a correction factor selected from Table 8.34. The correction factor adjusts the measured infiltration rates for the occurrence of less permeable soil horizons below the surface and the potential variability in the subsurface soil horizons throughout the infiltration site. This correction factor also accounts for the long-term infiltration capacity of the stormwater management facility.

To select the correction factor from Table 8.34, determine the ratio of the design infiltration rates for each location an infiltration measurement was performed. To determine this ratio, the design infiltration rate (Table 8.28) for the surface textural classification is divided by the design infiltration rate for the least permeable soil horizon. For example, a device with a loamy

sand at the surface and least permeable layer of loam will have a design infiltration rate ratio of about 2.7 and a correction factor of 3.5. The depth of the least permeable soil horizon should be within five feet of the proposed bottom of the device or to the depth of a limiting layer.

Table 8.34 Total Correction Factors Divided into Measured Infiltration Rates

Ratio of Design Infiltration Rates[2]	Correction Factor
1	2.5
1.1 to 4.0	3.5
4.1 to 8.0	4.5
8.1 to 16.0	6.5
16.1 or greater	8.5

[1] The method used to evaluate measured infiltration rates was developed by the Wisconsin Department of Natural Resources and is published in *Site Evaluation for Stormwater Infiltration (1002) Wisconsin Department of Natural Resources Conservation Practice Standards 02/04*.

[2] Ratio is determined by dividing the design infiltration rate (Table 8.33) for the textural classification at the bottom of the infiltration device by the design infiltration rate (Table 8.33) for the textural classification of the least permeable soil horizon. The least permeable soil horizon used for the ratio should be within five feet of the bottom of the device or to the depth of the limiting layer.

- ***Depth*** – The depth of an infiltration practice is a function of the maximum drawdown time and the design infiltration rate. Given the assumed infiltration rate for the practice, determine the maximum depth as follows:

$$D = i \times t$$

Where:

D	=	maximum depth of practice (inches)
i	=	infiltration rate (inches/hour)
t	=	maximum drawdown time (72 hours, 48 hours for MPCA permit)

- ***Effective Infiltration Area*** – Given the volume control standard (VCS) and the maximum depth of the practice (D) calculate the effective infiltration area where the effective infiltration area is defined as the area of the facility that is used to infiltrate runoff and does not include the area used for site access, berms and/or pretreatment.

For above ground practices that are rectangular in nature (infiltration basins with 3:1 side slopes or steeper)

$$A_i = V_w/D$$

Where:

A_i	=	effective infiltration area at the bottom of practice (ft^2)
V_w	=	design volume (e.g. VCS) (ft^3)
D	=	maximum depth of practice (feet) Note: *bottom of the infiltration practice should be at least three feet from the seasonally high groundwater table.*

For above ground practices that have angular sides slopes (infiltration basins with sides slopes shallower that 3:1)

$A_i = V_w/D$

Where:

A_i	=	effective infiltration area at half the volume of the practice* (*see Figure 8.11 below)* (ft^2)
V_w	=	design volume (e.g. VCS) (ft^3)
D	=	maximum depth of practice (feet) Note: *bottom of the infiltration practice should be at least three feet from the seasonally high groundwater table.*

* Since there is potentially a significant amount of infiltration that could occur though the sides of the practice, the design engineer should take this surface area into consideration thereby potentially reducing the overall footprint of the stormwater infiltration practice.

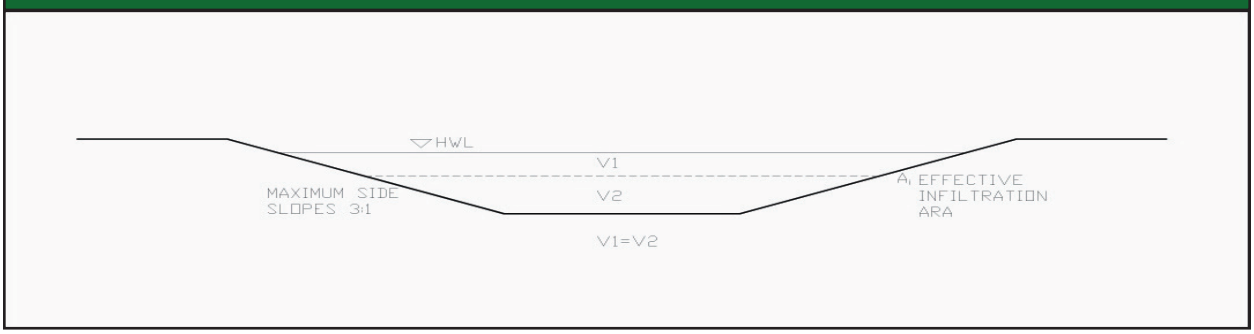
For underground practices (e.g. infiltration trenches, dry wells, subsurface infiltration practices)

$A_i = V_w/nD$

Where:

A_i	=	effective infiltration area is the sum of the bottom area and the sides of the practice* (ft^2)

Figure 8.11 Effective infiltration area for above ground practices with side slopes that are 3:1 or shallower



V_w	=	design volume (e.g. VCS) (ft^3)
n	=	porosity of filter media (range of porosity values for sands and gravels: 0.25 to 0.5)
D	=	maximum depth of practice (feet) Note: *maximum of 12 feet, and separated by at least three feet from seasonally high groundwater table*

For subsurface infiltration practices, use the procedure described above or technique recommended by manufacturer.

* Since underground facilities have potentially more surface area in contact with permeable soils, these practices should take these areas into consideration. Only that portion of the sides that is in contact with naturally permeable material should be used in calculating the effective infiltration area of the practice.

► ***Volume*** – The preliminary volume of the infiltration practice is determined by multiplying the average

basin area by the depth of the practice.

$V = A \times D$ *Total Storage Volume for Infiltration Basins and Underground Infiltration Systems*

Where:

V	=	Design volume for infiltration basin and underground infiltration system
A	=	average basin area (square feet)
D	=	depth of practice (feet)

For those practices that do not involve a media filter (e.g. infiltration basin and underground infiltration systems) this volume represents the total storage volume (design volume) of the practice. For those practices which do involve a media filter (e.g. infiltration trenches and dry wells) this volume represents the void space and the total storage volume will be greater. The following formula can be used to determine the total storage volume (design volume):

$V_T = A \times n \times D_i$ *Total Storage Volume for Infiltration Trenches and Dry Wells*

Where:

V_T	=	Design volume for infiltration trenches and dry wells (cubic feet)
A	=	average basin area (square feet)
n	=	porosity of filter media (range of porosity values for sands and gravels: 0.25 to 0.5)
D	=	depth of practice (feet)

Step 7. Size outlet structure and/or flow diversion structure, if needed (Note: Steps 5, 6, 7 and 8 are iterative)

It is HIGHLY RECOMMENDED that the outlet for the infiltration practice shall safely convey stormwater using all of the following mechanisms (Infiltration Basin, Wisconsin Department of Natural Resources Conservation Practice Standard 10/04).

- ***Drawdown valve*** – Infiltration basins may be designed with a draw down valve for the removal of standing water for maintenance and winter diversion.
- ***Emergency spillway*** – A means to release discharge in excess of the infiltration volume safely into the downstream stormwater conveyance system is REQUIRED.
- ***Freeboard*** – It is HIGHLY RECOMMENDED that two feet of freeboard be provided from the 100-year flood elevation of the infiltration practice to the lowest basement floor elevation of residential, commercial, industrial and institutional buildings located adjacent to the BMP, unless local requirements recommend otherwise.
- ***Drop Structure*** – Infiltration trenches or subsurface infiltration systems may be designed with a drop structure sized to handle the overflow. This additional volume of stormwater may be directed into the existing stormwater system or it may be diverted to a downstream BMP.

Step 8. Check volume, peak discharge rates and period of inundation against State, local and Watershed Management Organization requirements (Note: Steps 5, 6, 7 and 8 are iterative)

Follow the design procedures identified in the Unified Sizing Criteria section of the Manual to determine the volume control and peak discharge requirements.

Perform hand calculations or model the proposed development scenario using a surface water model

appropriate for the hydrologic and hydraulic design considerations specific to the site (see also Chapter 7 and 9 of the manual). This includes defining the parameters of the infiltration practice defined above: elevation and area (defines the storage volume), infiltration rate and method of application (effective infiltration area), and outlet structure and/or flow diversion information. The results of this analysis can be used to determine whether or not the proposed design meets the applicable requirements. If not, the design will have to be re-evaluated (back to Step 5).

The following items are specifically REQUIRED by the NWA Planned Unit Development, Inver Grove Heights City Code, or the MPCA Permit:

- *Recharge* ***Volume*** –The recharge volume is determined by taking the difference between the pre-development volume for the 5-year 24-hour event and the post-development volume for the same event. Recharge can be achieved either by a structural BMP (e.g. infiltration, bioretention, vegetated swale), better site design techniques, or a combination of both. If this criterion is not met, increase the storage volume of the infiltration practice or treat excess water quality volume (VCS) in an upstream or downstream BMP (see Step 5).
- ***Peak Discharge Rates*** – The intent of this sizing criterion is two-fold: controlling peak discharge for the 2-year 24-hour event prevents habitat degradation and erosion in urban streams (open ditch fl ow) and controlling peak discharge for the 10- and 100-year 24-hour events prevents flood damage to conveyance systems and infrastructure and reduces minor flooding caused by overbank floods.
- ***Period of Inundation*** – Infiltration practices shall discharge through the soil or filter media in 72 hours or less (48 hours if the practice is designed to meet the MPCA General Construction Permit). Additional flows that cannot be infiltrated or filtered in 72 hours should be routed to bypass the system through a stabilized discharge point. This criterion was established to provide the following: wet-dry cycling between rainfall events; unsuitable mosquito breeding habitat; suitable habitat for vegetation; aerobic conditions; and storage for back-to-back precipitation events. The period of inundation is defined as the time from the high water level in the practice to 3 to 6 inches above the invert of the outlet structure or drain tile or bottom of the facility. It is assumed that this range is less than 1/5 the bounce in the infiltration practice.

Other design requirements may apply to a particular site. The applicant should confirm local design criteria and applicability (see Step 3).

Step 9. Perform groundwater mounding analysis (Note: Steps 5, 6, 7 and 8 are iterative)

Ground water mounding, the process by which a mound forms on the water table as a result of recharge at the surface, can be a limiting factor in the design and performance of infiltration practices. A minimum of 3 feet of separation between the bottom of the infiltration practice and the seasonally high water table is REQUIRED (5 feet HIGHLY RECOMMENDED) to maintain the hydraulic capacity of the practice and provide adequate water quality treatment.

The most widely known and accepted analytical methods to solve for ground water mounding are based on the work by Hantush (1967) and Glover (1960). The maximum ground water mounding potential should be determined through the use of available analytical and numerical methods. Detailed ground water mounding analysis should be conducted by a trained hydrogeologist or equivalent as part of the site design procedure.

Step 10. Determine pretreatment volume and design pretreatment measures

See the section on pretreatment earlier in this section and Chapter 7 for specific pretreatment design guidance.

F. Links to Other Manuals

Georgia Stormwater Management Manual. 2001. Atlanta Regional Commission.
http://www.georgiastormwater.com/

Vermont Stormwater Management Manual. 2002.
http://www.vtwaterquality.org/stormwater.htm.

Wisconsin DNR Site Evaluation for Stormwater Infiltration Conservation Practice Standard 1002. 2004.
http://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm#Post.

Wisconsin DNR Infiltration Basin Conservation Practice Standard 1003. 2004.
http://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm#Post.

G. References

Bouwer, H. and R. C. Rice. 1989. Effect of Water Depth in Groundwater Recharge Basins on Infiltration. Journal of Irrigation and Drainage Engineering, Vol. 115, No. 4, pp. 556-567.

Georgia Stormwater Management Manual. 2001.

Glover, R., 1960. Mathematical Derivations as Pertain to Ground-water Recharge. Report CER60REG70. Agricultural Research Service, USDA, Fort Collins, Colorado. 81 pp.

Hantush, M., 1967. Growth and Decay of Groundwater-Mounds in Response to Uniform Percolation. Water Resources Research, 3(1): 227-234.

Rawls, W., D. Brakensiek, and K. Saxton, 1982. Estimation of Soil Water Properties, Transactions of the American Society of Agricultural Engineers. Vol. 25, No. 5, pp. 1316 – 1320 and 1328.

Rawls, W., D. Giminez, and R. Grossman, 1998. Use of Soil Texture, Bulk Density and Slope of water Retention Curve to Predict Saturated Hydraulic Conductivity, ASAE. Vol. 41(4), pp. 983 – 988.

Metropolitan Council Urban Small Sites Best Management Practice Manual. 2001.

Minnesota Pollution Control Agency Stormwater Best Management Practices Manual. 2000.

Natural Resources Conservation Service, 1986. Urban Hydrology for Small Watersheds, Technical Release 55 (TR-55). ftp://ftp.wcc.nrcs.usda.gov/downloads/hydrology_hydraulics/tr55/tr55.pdf

South Washington Watershed District (SWWD), 2005. 2004 Infiltration Monitoring Program Final Report. Emmons and Olivier Resources, Inc.

United States Department of Agriculture Natural Resources Conservation Service. TR-55, Urban Hydrology for Small Watersheds. Washington D.C., 1975.

U.S. Environmental Protection Agency, When are Storm Water Discharges Regulated as Class V Wells, June 2003

University of Wisconsin – Extension Wisconsin Storm Water Manual: Technical Design Guidelines for Storm Water Management Practices. 2000.

Winer, R. 2000. National Pollutant Removal Performance Database.

STORMWATER PONDS

Stillwater, MN

Definition:
A constructed basin situated to receive local stormwater runoff and hold designated volumes of runoff for specified periods of time. The objectives are to improve water quality through settling and biological uptake, and prevent downstream channel degradation or flood damage through storage and outflow rate reduction.

KEY CONSIDERATIONS

Design Criteria (for new construction):

- Irregularly shaped with minimum length to width ratio of 1.5:1
- Permanent pool volume of 1800 cubic feet per acre draining to pond.
- Permanent pool depth 3' minimum, 10' maximum at deepest points
- Extended detention (ED) storage sufficient to treat V_{wq}
- Pre-treatment required (sediment forebay sized at 10% of pond area recommended)
- Stabilized emergency overflow and energy dissipation at all outlets
- Side slopes not to exceed 1V:3H

Benefits:

- Able to effectively reduce many pollutant loads and control runoff flow rates
- Relatively straightforward design procedure
- Potential wildlife habitat and aesthetic or recreational enhancement
- May be used as temporary sedimentation basin during construction

Limitations:

- Relatively large space requirement
- Tends to increase water temperature and may cause downstream thermal impact
- Potential for nuisance insects or odor
- Problematic for areas of low relief, high water table, or near-surface bedrock
- Possible safety concerns

MANAGEMENT SUITABILITY

	Volume Control
X	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
	Wetland Bounce

MECHANISMS

	Infiltration
	Screening/ Filtration
	Temperature Control
X	Settling
X	Evaporation
	Transpiration
	Soil Adsorption (limited)
X	Biological/ Micro. Uptake

POLLUTION REMOVAL

80%	Total Suspended Solids
40%/30%	Nutrients - Total Phosphorus/ Total Nitrogen
60%	Metals - Cadmium, Copper, Lead, and Zinc
70%	Pathogens - Coliform, Streptococci, E. Coli
80%	Toxins - Chloride, Hydrocarbon, Pesticide

SITE FACTORS	
25 AC Min*	Drainage Area *10 AC possible if hydrology capable of supporting water levels
25%	Max. Site Slope
0*	Min. Depth to Bedrock *2 ft in PSH areas
0*	Min. Depth to Seasonally High Water Table *pond bottom must be above bedrock
C,D Preferred	NRCS Soil Type *A and B soils require liners
Poor*	Freeze/ Thaw Suitability *unless adapted with additional storage for snowmelt
Yes	Potential Hotspot Runoff *requires impermeable liner

Description:

Stormwater ponds are constructed basins placed in the landscape to capture stormwater runoff. The pond is graded and outlet structures are designed in such a way that specified volumes of water are either held until displaced by future runoff or detained for a specified period of time. While the runoff is being held in the pond, sediment and associated pollutants settle to the bottom. Pollutants can also be removed from the stormwater through microbial, plant and algal biological uptake.

Storage in a stormwater pond can be either permanent pool or extended detention storage. As the name implies, water in the permanent pool is meant to remain in the basin, allowing settling and biological uptake to occur between storms and protecting against sediment resuspension. To maintain a permanent pool over a period of time, the pond must be designed with a sufficiently large drainage area. Extended detention storage refers to the volume above the permanent pool which is controlled by an outlet structure, sized so that runoff from larger storms can be captured and released over a period of time, allowing some settling to occur and keeping flow rates in check.

Sediment and pollutant removal in stormwater ponds can be enhanced through the use of multiple cells in succession. In particular, a sediment forebay (pre-treatment basin) sized at 10% of the pond area should be considered upstream of the pond. This allows for settling of heavier materials in a designated area, enhancing the main pond performance and reducing the maintenance burden by concentrating the majority of sediments in one location.

It is also possible to design a pond with no extended detention storage (wet pond), in which the only outlet is the spillway and where 100% of the treated volume is within the permanent pool. When a storm occurs, the treated runoff in the pond is displaced by new (untreated) runoff. Wet ponds are able to fulfill water quality treatment requirements, but do not mitigate the channel degradation or flooding effects of increased flow from larger storms. Also, wet ponds are not generally recommended for cold climates because during frozen conditions, runoff can flow over the ice of the permanent pool, effectively negating the benefits of the intended treatment volume. Generally the most desirable pond configuration for Minnesota is a large enough permanent pool to meet water quality needs, and sufficient extended detention to ensure adequate treatment during frozen conditions.

A. Suitability

General

Generally speaking, the term “stormwater pond” may refer to any constructed basin that is built for the purpose of capturing and storing stormwater runoff, either temporarily or for an extended period of time, in order to prevent or mitigate downstream water quantity or quality impacts. Several distinct structure types (wet ponds, dry ponds, etc.) are included in this general category, and they are discussed in more detail below.

Function Within Stormwater Treatment Train

Stormwater ponds are typically installed as an end-of-pipe BMP at the downstream end of the treatment train. The use of stormwater ponds in Inver Grove Heights will regularly be for pretreatment prior to reaching an infiltration practice. At first this may seem as though it is requiring double the amount of stormwater treatment, while in reality this system is analogous to treating water with a stormwater pond and then discharging it to a surface water body. The pond is the same and the infiltration practice acts as the pipe that would normally take stormwater off-site. Stormwater pond size and outflow regulation requirements can be significantly reduced with the use of additional upstream BMPs.

Inver Grove Permit Applicability

One of the goals of this manual is to facilitate an understanding of and compliance with the city of Inver Grove Heights’ Volume Control Standard. This standard must be met on all new and re-development projects taking place in the northwest area.

Ponds generally may be used to meet the Inver Grove Heights pretreatment requirements. Stormwater ponding systems that incorporate infiltration may also reduce the 5-year 24-hour infiltration standard by the amount that the practice is able to store and infiltrate.

The following terms are thus used in the text to distinguish various levels of green roof design guidance:

REQUIRED:	Indicates design standards stipulated by the IGH PUD.
HIGHLY RECOMMENDED:	Indicates design guidance that is extremely beneficial or necessary for proper functioning of the practice, but is not specifically required by the City of Inver Grove Heights.
RECOMMENDED:	Indicates design guidance that is helpful for performance but not critical to the design.

Design Variants

Several distinct pond design variants are typically described in current stormwater management literature. While it is possible that any one of these pond types could be beneficially implemented somewhere in Inver Grove Heights, both the climatic conditions and the applicable regulations prevalent throughout the state strongly favor the use of one of them in particular, namely the wet extended detention pond. For this reason, much of the discussion in this chapter is focused primarily on wet extended detention ponds; however, all four main design variants are presented here for the sake of completeness.

1. ***Flow-through pond (no extended detention)***. Often called a “wet pond” in other literature, a pond that has an essentially unrestricted spillway as its primary outlet, with its crest at the elevation of the permanent pool. Provides water quality treatment by holding a volume of

stormwater equal to the permanent pool volume, permitting settling to occur. The water stored in the pond is later displaced by new runoff. The flow-through pond is generally not a good design option for Minnesota, because the storage volume allocated for treatment is entirely below the permanent pool, making it inaccessible to new runoff during frozen conditions (cold climate considerations are discussed in more detail below)

2. ***Wet extended detention pond.*** Indicates a combination of permanent pool storage and extended detention storage above the permanent pool to provide additional water quality or rate control.
3. ***Micropool extended detention pond***. Variation of the wet extended detention pond with a markedly smaller permanent pool at the pond outlet to prevent resuspension.
4. ***Dry pond.*** No permanent pool; relies only upon extended detention storage for its treatment volume. Highly susceptible to sediment resuspension and generally only useful for rate control.

Retrofit Suitability

Ponds are widely used for stormwater retrofits, and have two primary applications as a retrofit design. In communities where dry detention ponds were designed for flood control in the past, these facilities can be modified by adding a permanent wet pool for water quality treatment and adapting the outlet structure for channel protection. Alternatively, new ponds can be installed in available open areas as a part of a comprehensive watershed retrofit inventory.

Cold Climate Suitability

One of the biggest problems associated with proper pond operation during cold weather is the freezing and clogging of inlet and outlet pipes. To avoid these problems, the CWP (Caraco and Claytor, 1997) made some general design suggestions, which are adapted as follows:

- Inlet pipes should not be submerged, since this can result in freezing and upstream damage or flooding.
- Burying all pipes below the frost line can prevent frost heave and pipe freezing. Wind protection can also be an important consideration for pipes above the frost line. In these cases, designs modifications that have pipes “turn the corner” are helpful.
- Increase the slope of inlet pipes to a minimum of 1% to prevent standing water in the pipe, reducing the potential for ice formation. This design may be difficult to achieve at sites with flat local slopes.
- If perforated riser pipes are used, the minimum opening diameter should be ½”. In addition, the pipe should have a minimum 6” diameter.
- When a standard weir is used, the minimum slot width should be 3", especially when the slot is tall.
- Baffle weirs can prevent ice reformation during the spring melt near the outlet by preventing surface ice from blocking the outlet structure.
- In cold climates, riser hoods should be oversized and reverse slope pipes should draw from at least 6" below the typical ice layer.
- Alternative outlet designs that have been successful include using a pipe encased in a gravel jacket set at the elevation of the aquatic bench as the control for water quality events. This practice was both avoids stream warming and is also a non-freezing outlet.
- Trash racks should be installed at a shallow angle to prevent ice formation.

Water Quantity Treatment

Stormwater ponds are one of the best and most cost-effective methods for providing rate control which will require evaluation to meet the wetland bounce and duration standards. These goals are achieved with the use of extended detention storage, where runoff is stored above the permanent pool and released at a specified rate through a control structure. Depending upon the soil types, the stormwater pond can be

designed to provide volume control through the sides of the basin above the normal water level. Wherever an embankment is constructed to store water at a level higher than the surrounding landscape, dam safety regulations must be followed to ensure that downstream property and structures are adequately protected.

Water Quality Treatment

Ponds rely on physical, biological, and chemical processes to remove pollutants from incoming stormwater runoff. The primary treatment mechanism is gravitational settling of particulates and their associated pollutants as stormwater runoff resides in the pond. Another mechanism for the removal of pollutants (particularly nutrients) is uptake by algae and aquatic vegetation. Volatilization and chemical activity can also occur, breaking down and assimilating a number of other stormwater contaminants such as hydrocarbons.

The longer the runoff remains in the pond, the more settling (and associated pollutant removal) and other treatment can occur, and after the particulates reach the bottom of the pond, the permanent pool protects them from resuspension when additional runoff enters the basin. For these reasons, because they lack the crucial permanent pool, **dry extended detention ponds are not considered an acceptable option for meeting pretreatment goals.**

Removal efficiencies for key pollutants for wet / wet extended detention ponds are provided in Table 8.35.

Table 8.35 Reported Percent Removal of Key Pollutants

Practice	TSS [%]	Total Phosphorus [%]	Total Nitrogen [%]	Metals[1] [%]	Bacteria [%]	Hydro-carbons [%]
Wet Extended Detention Pond	80	50	30	60	70	80[2]

Notes:
1. Average of zinc and copper.
2. Based on fewer than five data points (i.e., independent monitoring studies)

Removals represent median values from Winer (2000) and have been rounded.

Typical effluent concentrations for selected water quality parameters are provided in Table 8.36.

Table 8.36 Typical BMP Effluent Concentrations

Practice	TSS [mg/l]	TP [mg/l]	TN [mg/l]	Cu [ug/l]	Zn [ug/l]
Wet Extended Detention Pond	10[1]	0.2[1]	1.3[2]	5.0[1]	30[1]

Values from (1) ASCE bmp database and (2) Winer 2000 (shaded values)

Limitations

The following general limitations should be recognized when considering installation of stormwater ponds:

- they consume a large amount of space
- they tend to increase water temperature and may cause downstream thermal impact

- they have the potential for nuisance insects or odor
- they are problematic for areas of low relief, high water table, or near-surface bedrock
- they pose safety concerns

B. Major Design Elements

Physical Feasibility Initial Check

Before deciding to use a pond for stormwater management, it is helpful to consider several items that bear on the feasibility of using a pond at a given location. The following list of considerations will help in making an initial judgment as to whether or not a pond is the appropriate BMP for the site.

- ***Drainage Area*** – 25 acres minimum HIGHLY RECOMMENDED, to ensure hydrologic input sufficient to maintain permanent pool; 10 acres (or less) may be acceptable, particularly if the groundwater table is intercepted and a water balance indicates that a permanent pool can be sustained.
- ***Space Required*** – Approximately 1-3% of the tributary drainage area is RECOMMENDED for the pond footprint.
- ***Site Topography and Slope*** – It is HIGHLY RECOMMENDED that slopes immediately adjacent to ponds be less than 25% but greater than 0.5 – 1% to promote flow towards the pond.
- ***Minimum Head*** – The elevation difference RECOMMENDED at a site from the inflow to the outflow is 6-10 feet.
- ***Minimum Depth to Water Table*** – In general, there is no minimum separation distance required with ponds. Intercepting the groundwater table can help sustain a permanent pool. However, some source water protection requirements may dictate a separation distance or an impervious liner if there is a sensitive underlying aquifer and the bottom material of the pond allows for infiltration.
- ***Soils*** – Underlying soils of hydrologic group “C” or “D” should be adequate to maintain a permanent pool. A liner will likely be needed for most group “A” soils and some group “B” soils. A site specific geotechnical investigation should be performed. Also, if earthen embankments are to be constructed, it will be necessary to use suitable soils.
- ***Wetlands*** – It is REQUIRED that stormwater ponds not be located in jurisdictional wetlands.
- ***Groundwater Protection*** – It is HIGHLY RECOMMENDED that ponds treating runoff from PSHs provide excellent pretreatment capabilities. In some cases (depending on the land use and associated activities), lining the pond may be necessary to protect groundwater, particularly when the seasonally high groundwater elevation is within three feet of the pond bottom.
- ***Shallow Soils and Bedrock*** – Pond use is limited due to the available depth that may require shallow water depths, affecting the surface area required as well as the aesthetics of the pond. Consider a wetland as an alternative.

Conveyance

Inflow Points

- It is HIGHLY RECOMMENDED that a forebay be provided at each inlet contributing greater than 10% of the total design storm inflow to the pond, to reduce the future pond maintenance burden.
- It is HIGHLY RECOMMENDED that inlet areas be stabilized to ensure that non-erosive conditions exist during 10-year storms.
- It is HIGHLY RECOMMENDED that rip-rap or other channel liners be extended below the permanent pool elevation.
- It is HIGHLY RECOMMENDED that inlet pipe inverts be located at the permanent pool elevation. Submerging the inlet pipe can result in freezing and upstream damage (Figure 8.12).

- It is HIGHLY RECOMMENDED that inlet pipes have a slope of no flatter than 1%, to prevent standing water in the pipe and reduce the potential for ice formation.
- It is HIGHLY RECOMMENDED that pipes be buried below the frost line, to prevent frost heave and pipe freezing.
- It is HIGHLY RECOMMENDED that where open channels are used to convey runoff to the pond, the channels be stabilized to reduce the sediment loads.

Adequate Outfall Protection

- It is HIGHLY RECOMMENDED that a stilling basin or outlet protection be used to reduce flow velocities from the principal spillway to non-erosive velocities (3.5 to 5.0 fps).
- Flared pipe sections that discharge at or near the stream invert or into a step-pool arrangement are RECOMMENDED over headwalls at the spillway outlet.
- It is RECOMMENDED that tree clearing be minimized along the downstream channel and that a forested riparian zone be reestablished in the shortest possible distance. It is also RECOMMENDED that excessive use of riprap be avoided, to minimize stream warming in channels with dry weather flow.
- Local agencies (Watershed Districts, Watershed Management Organizations (WMOs), municipalities, etc.) may have additional outlet control requirements.

Pretreatment

Construction of pretreatment measures immediately upstream of the main pond is HIGHLY RECOMMENDED, to reduce the maintenance requirements and increase the longevity of a stormwater treatment pond. A large portion of the overall sediment load (the heavier sediments) can be captured by relatively small (and therefore relatively easy to clean and maintain) BMPs. The larger pond area can thus be devoted to the settling of finer sediments, allowing it to fill more slowly and therefore requiring less frequent maintenance.

It is therefore HIGHLY RECOMMENDED that each pond have a sediment forebay or equivalent upstream pretreatment (non-pond BMPs may serve as pretreatment) at each inflow point that contributes greater than 10% of the inflow volume. A sediment forebay is a small pool, separated from the permanent pool by barriers such as earthen berms, concrete weirs, or gabion baskets, where initial settling of heavier particulates can occur.

- It is REQUIRED that where a forebay is installed, that direct vehicle/equipment access be provided to the forebay for sediment removal and other maintenance activities.
- It is HIGHLY RECOMMENDED that flows from forebays enter the permanent pool area with non-erosive outlet conditions.
- It is RECOMMENDED that the forebay(s) be sized to contain 10% of the volume control standard (VCS) in a pool that is four to six feet deep. The forebay storage volume counts toward the total permanent pool requirement.
- It is RECOMMENDED that the forebay(s) be designed with a surface area equivalent to 10% of the pond permanent pool surface area or equivalent to 0.1% of the drainage area.
- It is RECOMMENDED that a fixed vertical sediment depth marker be installed in the forebay to measure sediment deposition over time.
- It is RECOMMENDED that the bottom of the forebay be hardened, using concrete, asphalt, or grouted riprap, to make sediment removal easier.

Treatment

Permanent Pool and Volume Control Standard (VCS) Sizing

- Under the Inver Grove Heights Permit, it is REQUIRED that stormwater ponds designed for pretreatment to an infiltration area have permanent pool volume (dead storage) equal to at least 1800 cubic feet per acre of drainage to the pond. For example, a 30-acre drainage area requires a permanent pool volume of at least 54,000 cubic feet or 1.24 acre-feet.

- It is REQUIRED that permanent pool depths be a minimum of three feet and maximum of 10 feet at the deepest points. Where phosphorus load reductions are a priority, it is RECOMMENDED that a maximum depth of eight feet be used, to limit the likelihood of stratification and the potential for bottom sediment to release phosphorus.
- It is REQUIRED that the VCS be released at a rate not to exceed 5.66 cfs per acre of permanent pool surface area.
- Where phosphorus load reductions are a priority, permanent pool volumes as large as 3600 cubic feet per acre of drainage are RECOMMENDED for enhanced removal.
- A water balance is RECOMMENDED to document sufficient inflows to maintain a constant permanent pool during prolonged dry weather conditions.
- To compensate for ice build-up on the permanent pool, twelve inches of additional storage can be provided. This is an alternative to the preferred active management strategy of drawing down the permanent pool seasonally to provide detention while the permanent pool is frozen.
- Using pumps or bubbling systems can reduce ice build-up and prevent the formation of an anaerobic zone in pond bottoms. Caution must be exercised, however, because of the possibility of thin or no ice cover.

Pond Liners

It is HIGHLY RECOMMENDED that pond liners be considered in circumstances where a permanent pool is needed but difficult to maintain due to site conditions, or where seepage from the pond into the groundwater would otherwise occur but must be avoided. This includes:

- Areas with Hydrologic Group A soils, gravel, or fractured bedrock.
- Potential Stormwater Hotspots (PSHs)

If geotechnical tests confirm the need for a liner, acceptable options include: (a) six to 12 inches of clay soil, including bentonite, (minimum 15% passing the #200 sieve and a maximum permeability of 1 x 10^{-5} cm/sec), (b) a 30 ml poly-liner, or (c) engineering design as approved on a case-by-case basis by Inver Grove Heights city engineer.

Grading and Site Layout

The site layout and pond grading affect the pollutant removal capability of the pond as well as the ease of maintenance. Performance is enhanced when multiple treatment pathways are provided by using multiple cells, longer flowpaths, high surface area to volume ratios, complex microtopography, and/or redundant treatment methods (combinations of pool, ED, and marsh). It is RECOMMENDED that a berm or simple weir be used instead of pipes to separate multiple ponds, because of the higher freezing potential of pipes. Specific guidelines are provided below:

- It is HIGHLY RECOMMENDED that pond side slopes within the permanent pool (below the aquatic bench) not exceed 2:1 (H:V).
- It is HIGHLY RECOMMENDED that side slopes to the pond should be 3:1 or flatter, and that they terminate on a safety bench (see next section).
- It is RECOMMENDED that approximately 15% of the permanent pool surface area be allocated to a shallow (i.e., less than or equal to 18” in depth) zone along the perimeter to promote a shallow marsh littoral zone.
- It is RECOMMENDED that the minimum length to width ratio for ponds be 1.5:1.
- It is RECOMMENDED that the maximum drainage area to surface area ration be 100:1.
- It is RECOMMENDED that to the greatest extent possible, ponds should be irregularly shaped and long flow paths should be maintained.

Pond Benches

All pond designs should incorporate an access bench (a shallow slope area adjacent to the pond, preventing people from slipping into the water) and a submerged aquatic bench (a shallow slope area just inside the pond perimeter, facilitating the growth of aquatic plants).

- Safety Bench: It is HIGHLY RECOMMENDED that an access bench extending 10 feet outward from the permanent pool edge to the toe of the pond side slope be provided. Narrower benches may be used on sites with extreme site limitations. The maximum cross-slope of the safety bench should be 6%. Safety benches are not needed when the pond side slopes are 4:1 or flatter.
- Aquatic Bench: It is HIGHLY RECOMMENDED that an irregularly configured aquatic bench, extending up to 10 feet inward from the normal shoreline and graded no more than eighteen inches below the permanent pool water surface elevation, be incorporated into the pond.

Maintenance Access

- It is REQUIRED that adequate maintenance access be provided. It is HIGHLY RECOMMENDED that the access be at least 12 feet wide, have a maximum slope of 15%, and be appropriately stabilized for use by maintenance equipment and vehicles. Steeper grades may be allowable if designed using appropriate materials for the grade.
- It is REQUIRED that the maintenance access extend to the forebay, safety bench, riser, and outlet, and allow vehicles to turn around.

Riser in Embankment

- It is REQUIRED that the riser be located so that short-circuiting between inflow points and the riser does not occur.
- It is RECOMMENDED that the riser be located within the embankment for maintenance access, prevention of ice damage, and aesthetics.

Spillway Design

The principle spillway (riser) should be designed for the desired release rates while keeping the future maintenance needs in mind. Lessening the potential for clogging and freezing, creating safe access paths for inspection and maintenance, barring access to children and vandals, and allowing safe draw down of the permanent pool when necessary are goals of riser design that consider long-term maintenance needs.

Non-clogging Low Flow Orifice

- It is HIGHLY RECOMMENDED that the low flow orifice be adequately protected from clogging by either an acceptable external trash rack (recommended minimum orifice of 3") or by internal orifice protection that may allow for smaller diameters (recommended minimum orifice of 1"). Appendix A contains design details for both low flow orifice protection options.
- The RECOMMENDED method is a submerged reverse-slope pipe that extends downward from the riser to an inflow point at least one foot below the normal pool elevation (see Appendix A for a typical detail). This should also draw from at least 6” below the typical ice layer, but to avoid sediment deposition, the pipe should not be installed on the pond floor
- Alternative methods are to employ a broad crested rectangular, V-notch, or proportional weir, protected by a half-round CMP that extends at least 12 inches below the normal pool. It is HIGHLY RECOMMENDED that the minimum weir slot width be 3”, especially when the slot is tall. It is RECOMMENDED that hoods over orifices be oversized to account for ice formation.

Trash Racks

- It is REQUIRED that basin outlets be designed to prevent discharge of floating debris. It is HIGHLY RECOMMENDED that the principal spillway openings be equipped with removable trash racks to prevent clogging by large debris and to restrict access to the interior for safety purposes. Recommended openings are 8 inches.
- It is RECOMMENDED that trash racks be installed at a shallow (~15°) angle to prevent ice formation.
- Baffle weirs (essentially fences in the pond) can prevent ice reformation during the spring melt near the outlet by preventing surface ice from blocking the outlet structure.

Pond Drain

It is HIGHLY RECOMMENDED that each pond be equipped with a drain that can dewater the pond to the maximum extent possible within 24 hours. The drain pipe should have an elbow or protected intake extending at least 12" above the bottom of the permanent pool to prevent deposited sediment from clogging the pipe.

Adjustable Gate Valve

- It is RECOMMENDED that the pond drain and possibly the low flow orifice be equipped with an adjustable gate valve (typically a handwheel activated knife gate valve). These valves should be located inside the riser, where they (a) will not normally be inundated and (b) can be operated in a safe manner. To prevent vandalism that alters the pond level, the handwheel should be chained to a ringbolt, manhole step or other fixed object.
- It is RECOMMENDED that both the low flow orifice pipe and the pond drain be sized one pipe size greater than the calculated design diameter and the gate valve used to adjust the opening to an equivalent diameter.

Riser Access

It is RECOMMENDED that lockable manhole covers and manhole steps within easy reach of valves and other controls be installed, to allow for inspector access and prevent vandalism.

Emergency Spillway

It is REQUIRED that an emergency spillway should be provided to pass storms in excess of the pond hydraulic design. It is also REQUIRED that the spillway be stabilized to prevent erosion and designed in accordance with applicable dam safety requirements (NRCS Pond Standard 378 and MnDNR dam safety guidelines). The emergency spillway must be located so that downstream structures will not be impacted by spillway discharges. If the spillway crosses the maintenance access, materials meeting the appropriate load requirements must be selected.

Landscaping

Landscaping Plan

It is HIGHLY RECOMMENDED that a landscaping plan for the stormwater pond and the surrounding area be prepared to indicate how aquatic and terrestrial areas will be stabilized and established with vegetation (see Appendix B for detailed guidance). The following guidance suggests how landscaping can be incorporated into pond design.

- Woody vegetation should not be planted or allowed to grow within 15 feet of the toe of the embankment or 25 feet from the inlet and outlet structures.
- Wherever possible, wetland plants should be encouraged in a pond design, either along the aquatic bench (fringe wetlands), the access bench and side slopes (ED wetlands) or within shallow areas of the pool itself.
- The best elevations for establishing wetland plants, either through transplantation or volunteer colonization, are within six inches (plus or minus) of the normal pool.
- The soils of a pond buffer are often severely compacted during the construction process to ensure stability. The density of these compacted soils can be so great that it effectively prevents root penetration, and therefore, may lead to premature mortality or loss of vigor. Consequently, it is advisable to excavate large and deep holes around the proposed planting sites, and backfill these with uncompacted topsoil or other organic material (see bioretention specifications).
- As a rule of thumb, planting holes should be three times deeper and wider than the diameter of the rootball (of balled and burlap stock), and five times deeper and wider for container grown stock. This practice should enable the stock to develop unconfined root systems.
- Species that require full shade, are susceptible to winterkill, or are prone to wind damage should be avoided. Extra mulching around the base of the tree or shrub is strongly recommended as a means of conserving moisture and suppressing weeds.

Pond Buffers and Setbacks

- It is REQUIRED (Minnesota Department of Health Rule 4725.4350) that a 50' setback between stormwater ponds and water supply wells be provided.
- It is HIGHLY RECOMMENDED that a pond buffer extending 25 feet outward from the maximum water surface elevation of the pond be provided. Permanent structures (e.g., buildings) should not be constructed within the buffer. This distance may be greater under local regulations.
- The pond buffer should be contiguous with other buffer areas that are required by existing regulations (e.g., stream buffers).
- It is HIGHLY RECOMMENDED that existing trees should be preserved in the buffer area during construction. It is desirable to locate forest conservation areas adjacent to ponds. To help discourage resident geese populations, the buffer can be planted with trees, shrubs and native ground covers.

Safety

- It is REQUIRED that public safety be considered in every aspect of pond design.
- The principal spillway opening should not permit access by small children, and endwalls above pipe outfalls greater than 48 inches in diameter should be fenced to prevent a hazard.
- The access and aquatic benches should be landscaped to prevent access to the pond.
- Warning signs prohibiting swimming, skating, and fishing should be posted.
- Pond fencing is generally not encouraged. A preferred method is to grade the pond to eliminate steep drop-offs or other safety hazards.
- Dam safety regulations should be strictly followed with pond design to ensure that downstream property and structures are adequately protected.

C. Construction Details and Specifications

CADD based details for pond systems are contained in Appendix A. The following details, with specifications, have been created for stormwater ponds:

- Stormwater pond plan
- Stormwater pond profile
- Pond inlet
- Riser pipe outlet structure

D. Operation and Maintenance

Overview

Maintenance is necessary for a stormwater pond to operate as designed on a long-term basis. The pollutant removal capabilities of ponds will decrease if:

- Permanent pool elevations fluctuate
- Debris blocks the outlet structure
- Pipes or the riser are damaged
- Invasive plants out-compete the wetland plants
- Sediment accumulates in the pond, reducing the storage volume
- Slope stabilizing vegetation is lost
- The structural integrity of the embankment, weir, or riser is compromised.

Pond maintenance activities range in terms of the level of effort and expertise required to perform them. Routine pond and wetland maintenance, such as mowing and removing debris or trash, is needed multiple times each year. Owners may consider an "adopt-a-pond" program in which properly trained citizen volunteers perform basic landscape maintenance activities (the City of Plymouth, for example, has instituted such a program). More significant maintenance such as removing accumulated sediment is needed less frequently, but requires more skilled labor and special equipment. Inspection and repair of critical structural features such as embankments and risers, needs to be performed by a qualified professional (e.g., structural engineer) that has experience in the construction, inspection, and repair of these features.

Design Phase Maintenance Considerations

Implicit in the design guidance in the previous sections, many design elements of pond systems can minimize the maintenance burden and maintain pollutant removal efficiency. Key maintenance considerations are providing access for inspection and maintenance, and designing all outlets and the principal spillway to minimize clogging. Providing easy access (typically 8 feet wide) to all pond components for routine maintenance is REQUIRED.

Stormwater ponds can be properly designed, constructed and maintained to minimize the likelihood of being desirable habitat for mosquito populations. Designs that incorporate constant inflows and outflows, habitat for natural predators, and constant permanent pool elevations limit the conditions typical of mosquito breeding habitat (see also Ch. 6 discussion on mosquito control).

Construction Phase Maintenance

The construction phase is another critical step where O&M issues can be minimized or avoided.

Inspections during construction are needed to ensure that the practice is built in accordance with the approved design standards and specifications. Detailed inspection checklists should be used that include sign-offs by qualified individuals at critical stages of construction, to ensure that the contractor's interpretation of the plan is acceptable to the professional designer. An example construction phase inspection checklist is provided in Appendix D.

Post-Construction Operation and Maintenance

Operation to Address Frozen Conditions

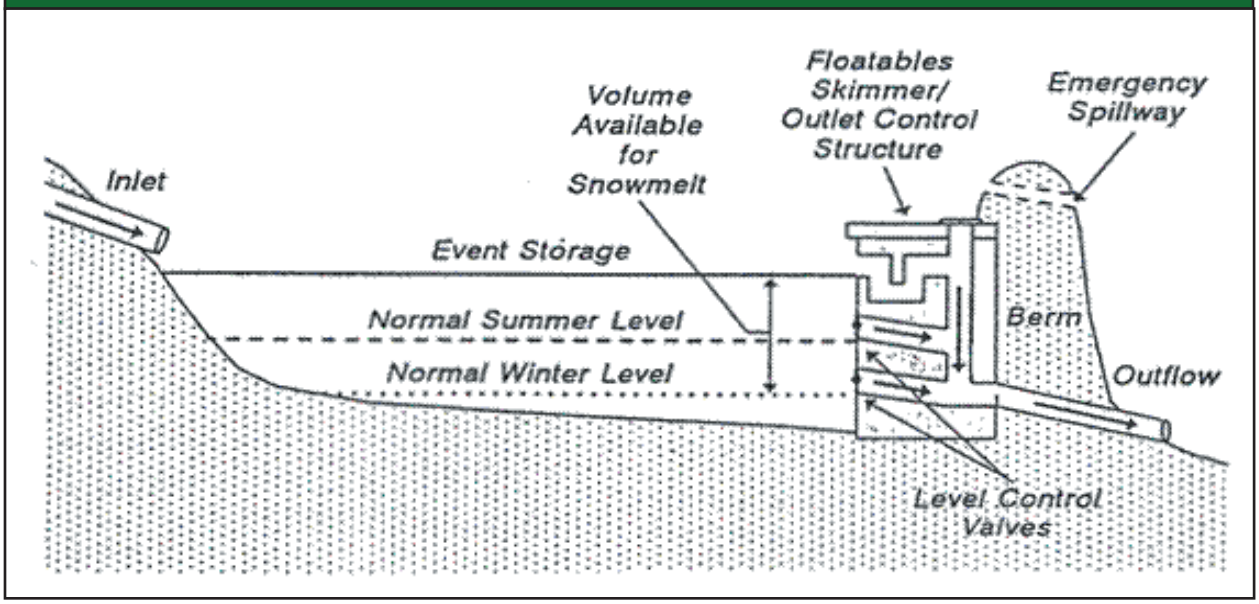
It is HIGHLY RECOMMENDED that the O&M plan include a provision to lower the level of the permanent pool in the late fall, to provide additional retention storage for snowmelt runoff and ensure that some permanent pool storage is available above the ice (as Figure 8.12 illustrates, the permanent pool should not be completely eliminated nor allowed to freeze through completely).

Maintenance

Some important post construction maintenance considerations are provided below. A more detailed checklist of maintenance activities and associated schedules is provided in Appendix F. More detailed maintenance guidance can be found in the Pond and Wetland Maintenance Guidebook (CWP, 2004).

- ► It is REQUIRED that a legally binding and enforceable maintenance agreement be executed between the practice owner and the local review authority.
- ► Adequate access must be provided for inspection, maintenance, and landscaping upkeep, including appropriate equipment and vehicles. It is RECOMMENDED that a maintenance right of way or easement extend to ponds from a public or private road.
- ► It is HIGHLY RECOMMENDED that ponds be inspected annually during winter freeze periods to look for signs of improper operation.

Figure 8.12 Frozen condition pond outlet



- It is HIGHLY RECOMMENDED that sediment removal in the forebay occur every 2 to 7 years or after 50% of total forebay capacity has been lost. In areas where road sand is used, an inspection of the forebay and stormwater wetland should be scheduled after the spring melt to determine if clean-out is necessary.
- Sediments excavated from stormwater ponds that do not receive runoff from confirmed hotspots are generally not considered toxic or hazardous material, and can be safely disposed by either land application or land filling. Sediment testing may be necessary prior to sediment disposal when a confirmed hotspot land use is present.
- Periodic mowing of the pond buffer is HIGHLY RECOMMENDED along maintenance rights-of-way and the embankment. The remaining buffer can be managed as a meadow (mowing every other year), prairie, or forest.
- Ponds should not be drained during the spring, as temperature stratification and high chloride concentrations at the bottom can occur, which could result in negative downstream effects.
- Care should be exercised while draining the pond to prevent rapid release and minimize the discharge of sediments or anoxic water. The approving jurisdiction should be notified before draining a pond.
- It is REQUIRED that OSHA safety procedures be followed for maintenance activities within enclosed areas, such as outlet structures.

General maintenance activities and schedule are provided in Table 8.37.

Table 8.37 Typical Inspection/Maintenance Frequencies for Ponds

Inspection Items	Maintenance Items	Frequency
► Ensure that at least 50% of wetland plants survive ► Check for invasive wetland plants	► Replant wetland vegetation	One time - After First Year
► Check that maintenance access is free and clear ► Inspect low flow orifices, reverse flow pipes, and other pipes for clogging ► Check the permanent pool or dry pond area for floating debris, undesirable vegetation ► Investigate the shoreline for erosion ► Monitor wetland plant composition and health ► Look for broken signs, locks, and other dangerous items.	► Mowing – minimum Spring and Fall ► Remove debris ► Repair undercut, eroded, and bare soil areas	Monthly to Quarterly or After Major Storms (>1")
► Monitor wetland plant composition and health ► Identify invasive plants ► Ensure mechanical components are functional	► Trash and debris clean-up day ► Remove invasive plants ► Harvest wetland plants ► Replant wetland vegetation ► Repair broken mechanical components if needed	Semi-annual to annual
► All routine inspection items above ► Inspect riser, barrel, and embankment for damage ► Inspect all pipes ► Monitor sediment deposition in facility and forebay	► Pipe and Riser Repair ► Forebay maintenance and sediment removal when needed	Every 1 to 3 years
► Monitor sediment deposition in facility and forebay	► Forebay maintenance and sediment removal when needed	2-7 years
► Remote television inspection of reverse slope pipes, underdrains, and other hard to access piping	► Sediment removal from main pond/wetland ► Pipe replacement if needed	5-25 years

Cost Considerations

Costs for ponds typically include costs for embankment, riser and spillway structures, outfall protection, vegetative stabilization, excavation, and grading. Additional costs for site preparation can include soil amendments, precision grading, plant materials and creation of occluding layers in coarse-textured soil types if wetlands systems must be created on upland sites due to project constraints. Project costs can be lowered if existing pre-construction site conditions are carefully considered and isolated areas with hydric soils contained within the footprint of the project are utilized as stormwater management facilities.

Additional maintenance costs will be incurred until the establishment of the wetland ecosystem. Invasive plants must be culled and dead plants replaced. The outlet structure may have to be adjusted, based on seasonal observations, to achieve the proper water surface in the pond.

Construction and Maintenance Costs

Utilizing Table 8.38 and the cost estimation worksheet in Appendix F, will allow designers to avoid over or under estimation of fixed costs.

Table 8.38 lists the specific site components that are specific to stormwater ponds. Not included in this table are those cost items that are common to all construction projects, such as mobilization, traffic control, erosion and sediment control, permitting, etc. A more detailed worksheet, utilizing 2005 construction prices, is contained in Appendix F.

Table 8.38 Cost Components for Stormwater Ponds

Implementation Stage	Primary Cost Components	Basic Cost Estimate	Other Considerations
Site Preparation	Tree & plant protection	Protection Cost ($/acre) x Affected Area (acre)	Removal of existing structures, topsoil removal and stockpiling
	Topsoil salvage	Salvage cost ($/acre) x Affected Area (acre)	
	Clearing & grubbing	Clearing Cost ($/acre) x Affected Area (acre)	
Site Formation	Excavation / grading	8-ft Depth Excavation Cost ($/acre) x Area (acre)	Soil & rock fill material, tunneling
	Hauling material offsite	Excavation Cost x (% of Material to be hauled away)	
Structural Components	Inlet structure	($/structure)	Pipes, catchbasins, manholes, valves
	Outlet structure	($/structure)	
Site Restoration	Seeding or sodding	Seeding Cost ($/acre) x Seeded Area (acre)	Tree protection, soil amendments, seed bed preparation, trails
	Planting / transplanting	Planting Cost ($/acre) x Planted Area (acre)	
Annual Operation, Maintenance, and Inspection	Debris removal	Removal Cost ($/acre) x Area (acre) x Frequency (2 / 1yr)	Vegetation maintenance, cleaning of structures
	Sediment removal	Removal Cost ($/acre) x Area (acre) x Frequency (1 / 5yr)	
	Gate / valve operation	Operation Cost ($) x Operation Frequency (2 / 1 yr)	
	Inspection	Inspection Cost ($) x Inspection Frequency (2 / 1 yr)	
	Mowing	Mowing Cost ($) x Mowing Frequency (4 / 1 yr)	

E. Design Procedure

The following steps outline a recommended design procedure for a wet extended detention pond (wet sedimentation basin) in compliance with the Inver Grove Heights Stormwater Permit. Design recommendations beyond those specifically required by the permit are also included and marked accordingly.

Design Steps

Step 1. Make a preliminary judgment as to whether site conditions are appropriate for the use of a stormwater pond, and identify the function of the pond in the overall treatment system

A. Consider basic issues for initial suitability screening

- ► Site drainage area
- ► Depth to water table
- ► Depth to bedrock
- ► Presence of wetlands
- ► Soil characteristics
- ► Receiving water(s)

B. Determine how the pond will fit into the overall stormwater treatment system.

- ► In Inver Grove Heights, stormwater ponds will generally be used for pretreatment upstream of an infiltration practice.
- ► Determine whether the pond needs to treat the volume control standard (VCS)
- ► Determine whether the pond is being designed as a wet detention pond under the MPCA General Stormwater Permit for Construction Activities.
- ► Determine whether the pond will be used as a temporary sediment basin during construction.
- ► Decide where on the site the pond is most likely to be located.

Step 2. Confirm design criteria and applicability.

A. Determine whether the pond must comply with the MPCA Permit.
B. Check with Inver Grove Heights officials, WMOs, and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 3. Confirm site suitability

A. Perform field verification of site suitability.

- ► If the initial evaluation indicates that a pond would be a good BMP for the site, it is RECOMMENDED that a minimum of three soil borings or pits be dug in the same location as the proposed pond to verify soil types and to determine the depth to groundwater and bedrock.
- ► It is RECOMMENDED that the minimum depth of the soil borings or pits be five feet below the bottom elevation of the proposed pond.
- ► It is HIGHLY RECOMMENDED that the field verification be conducted by a qualified geotechnical professional.

B. Perform water balance calculations if needed.

Step 4. Compute volume control standard (VCS) and permanent pool volume.

Refer to Chapter 7 for information on computing the volume control standard.

If the pond is being designed as a wet detention pond for new construction under the MPCA Permit, then a permanent pool volume equal to 1800 cubic feet for each acre draining to the pond is REQUIRED. This can be calculated as:

$$\text{Permanent Pond Volume} = 1800\left[\frac{ft^3}{Ac}\right] * A\left[Ac\right] \ [ft3]$$

If the pond will be used for temporary sediment control during construction, the associated permanent pool volume REQUIRED is either the 2 year, 24 hour storm runoff volume draining to the pond (with minimum 1800 cubic feet for each acre draining to the basin), or in the absence of such a calculation, 3600 cubic feet for each acre draining to the basin. It is also REQUIRED that sediment deposited during construction be removed before normal operation begins (refer to MPCA Permit for additional design requirements).

If part of the overall VCS is to be treated by other BMPs, subtract that portion from the VCS to determine the part of the VCS to be treated by the pond. It is assumed that the pond will be the only BMP used for rate control for larger storms.

Details on the Stormwater Sizing Criteria are found in Chapter 7.

Step 5. Determine pretreatment (sediment forebay) volume (HIGHLY RECOMMENDED).

In the absence of adequate upstream treatment by other BMPs, it is HIGHLY RECOMMENDED that a sediment forebay or similarly effective pretreatment system be provided at each inlet providing 10% or more of the total design inflow, with a RECOMMENDED volume equal to 10% of the permanent pool volume in a pool 4 to 6 feet deep. The forebay storage volume counts toward the total permanent pool requirement. Likewise, the storage volumes from other BMPs used upstream in the treatment train count toward the total permanent pool requirement and thus may be subtracted.

Step 6. Consider volume control standard variations for frozen conditions (HIGHLY RECOMMENDED).

When the pond and sediment forebay are frozen, much of the storage is rendered ineffective because stormwater runoff can flow over the ice and bypass the intended treatment. To alleviate this problem, additional extended detention storage (which is available even under frozen conditions) can be designed into the pond by increasing the extended detention storage volume designated for water quality control, or by adding a weir structure to the sediment forebay overflow area.

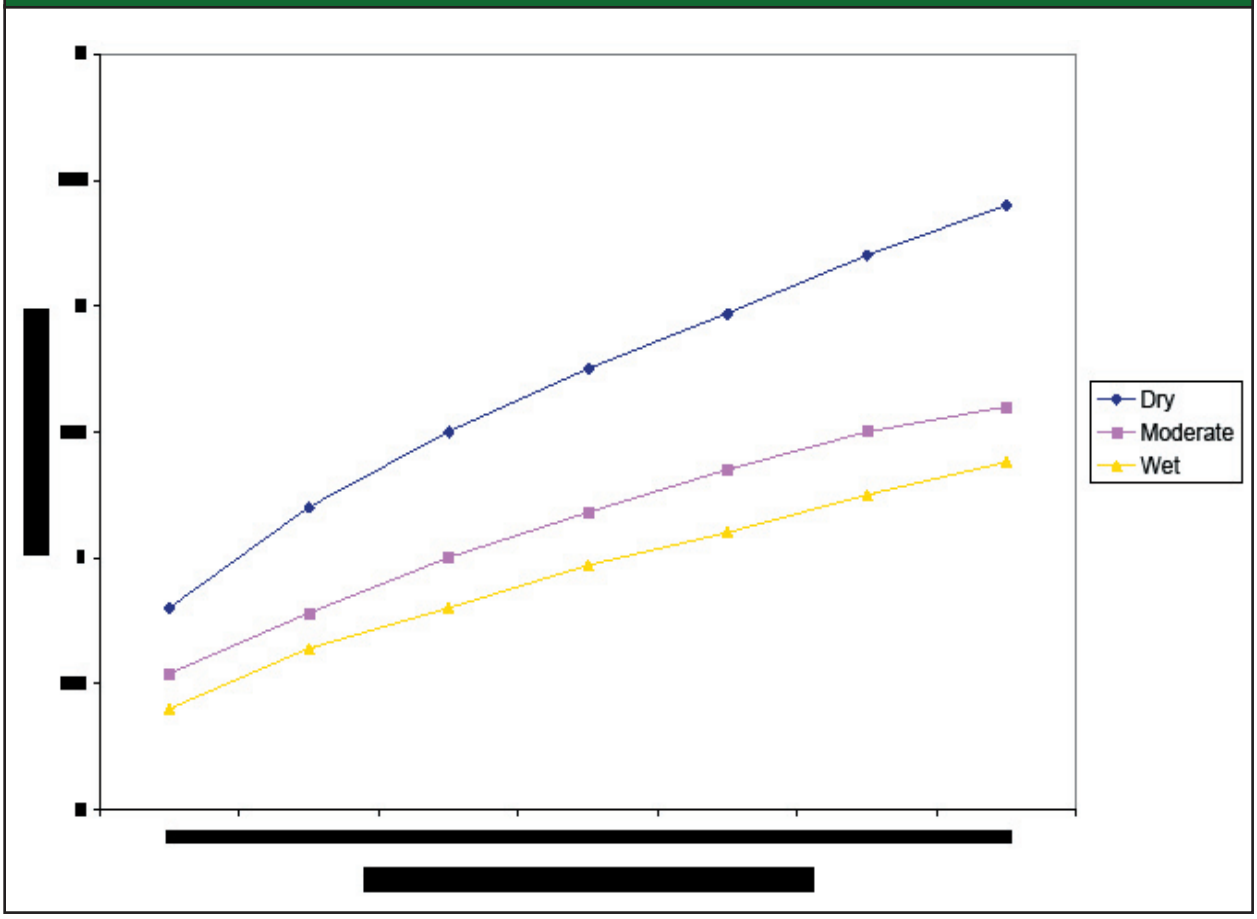
The average snowmelt volume can be computed from the following equation:

Average snowmelt volume (depth/unit area)	=	Average snowpack depth at the initiation of the snowmelt period	x	Typical snowpack water at time of melt	–	Estimated infiltration volume likely to occur during a 10-day melt period.

Table 8.38 and Figure 8.13 will allow the designer to determine both the average depth of snowpack existing at the start of spring snowmelt, plus the water content of the snowpack during the month of March.

Table 8.39 Snow Statistics for Inver Grove Heights	
Average Annual Snowfall	50 inches
Snow Depth at Initiation of Melt	7 inches (median snow depth on March 10)

Figure 8.13 Snowmelt Infiltration Based on Soil Moisture Content



Source: Adapted from Granger et al. 1984)

Snow Water Equivalent for March	0.12 (water inch / snow inch)

Source: Minnesota Climatology Working Group

Step 7. Determine location and preliminary geometry.

The preliminary grading plan can be developed with the following procedure:

1. Locate the pond in the lowest elevation area of the site (not in a jurisdictional wetland) and provide space around the pond for maintenance access. Adequate maintenance access is REQUIRED. 12' minimum width is HIGHLY RECOMMENDED.
2. Establish a primary outlet elevation (normal water level) and/or a pond bottom elevation.
3. Provide storage for the permanent pool below the primary outlet elevation in the main pond area.
4. Include an aquatic bench extending into the permanent pool and a access bench extending out

from the permanent pool.

5. Considering the desired pond footprint for the VCS and larger storms. While developing the grading plan, consider the desired (or required) length to width ratio and side slopes detailed earlier in this section (or in applicable regulations).
6. Once the preliminary grading plan has been developed, determine the associated stage-storage relationship for water surface elevations through the maximum expected levels.

The approximate storage corresponding to a given stage (elevation) can be determined using the average end area method. The area within each of the closed contour lines on the grading plan representing the pond is measured, and the average area of each set of adjacent contours is computed. The approximate volume between the two contours is then calculated as the average area multiplied by the elevation difference. Where $V_{1\text{-}2}$ is the volume between contour 1 and contour 2, A_1 and A_2 are the areas within closed contours 1 and 2, respectively, and E_1 and E_2 are the elevations of contours 1 and 2, respectively.

Cumulative volume above the bottom of the pond, or above the normal water surface elevation, can be calculated by adding subsequent incremental volumes. This is readily accomplished with the use of a spreadsheet prepared as follows (the first row of the table below contains the spreadsheet column header,

$$V_{1-2} = \frac{A_1 + A_2}{2} \times (E_2 - E_1)$$

the second row is column description, and the third, fourth, and fifth rows provide an example, with a permanent pool elevation of 902):

Table 8.40 Example Volume Calculation

Spreadsheet Column Header	Elevation	Area	Average Area	Depth	Volume	Cumulative Volume	Volume Above Permanent Pool
Spreadsheet Column Description	Elevation of Pond Contour Line	Area enclosed by Contour Line	Average area of current and previous rows	Elevation difference between current and previous rows	Volume between current and previous contour	Volume between current and lowest contour	Volume between current and permanent pool contour
Example value	900	1000	N/A	N/A	N/A	0	N/A
Example value	902	1200	1100	2	2200	2200	0
Example value	904	1600	1400	2	2800	5000	2800

The stage-storage relationship will be used to develop a stage-storage-discharge table as outlet structures are designed. This is an iterative process that may include revising the preliminary grading plan and subsequently redetermining the stage-storage relationship (or using an acceptable model to check).

Step 8. Size and design outlet structures.

The following outlet stages should be included in the pond design. It is possible to design one device to meet all stages. Equations included in this step are based on certain assumptions about which types of outlet structures will be used to control the various stages. If the designer chooses to use different structure types, the specific equations used to determine stage-discharge relationships will change, but the general approach will remain the same.

- Emergency drain: a drawdown pipe sized to drain the pond within 24 hours to allow access for riser repairs and sediment removal, or to lower the permanent pool in late fall (to provide additional storage during frozen conditions).
- Water quality (low flow) outlet: an outlet (typically an orifice) designed to release VCS with an average detention time of 12 hours. After designing the orifice, a check should be made to verify that the release rate is no greater than 5.66 cfs/acre of pond surface area. (Calculation steps adapted from Vermont Stormwater Management Manual.)

The average release rate for VCS is computed as:

$$Q_{VCS_avg} = \frac{VCS}{t_{VCS}}$$

Where t_{VCS} is the intended VCS detention time. From the stage-storage table, find the elevation associated with VCS. Calculate the approximate average head on the volume control outlet as:

$$h_{vcs_avg} = \frac{Evcs - E_{PermPool}}{2}$$

Where E_{vcs} is the VCS pool elevation and $E_{PermPool}$ is the elevation of the permanent pool (the invert of the VCS orifice).

The required orifice cross sectional area can then be indirectly computed using the orifice equation:

$$Q_{VCS} = CA_{VCS}\sqrt{2gh_{VCS}}$$

Where C is the orifice coefficient (0.6 is typically used, but may not apply in all cases), A_{VCS} is the orifice area, and g is gravitational acceleration.

The diameter of the orifice is then

$$d_{WQ} = 2 \cdot \sqrt{\left(\frac{A_{VCS}}{\pi}\right)}$$

The rate of discharge from the orifice for any head value h_{VCS} on the orifice can then be computed as:

$$Q_{VCS_avg} = CA_{VCS}\sqrt{2gh_{VCS_avg}}$$

- Rate Control Standard (RCS) outlet: an outlet designed to release the 10-year rainfall over a period of 24 hours (minimum RCS detention time is 12 hours). The RCS pool elevation can be read from the pond stage-storage relationship.

Assuming an orifice is also used to release RCS the invert of the RCS orifice may be placed at the VCS pool elevation (E_{VCS}).

The average release rate for RCS is computed as:

$$Q_{RCS_avg} = \frac{RCS_V - VCS_V}{t_{RCS}} - Q_{VCS}$$

Where t_{RCS} is the intended RCS detention time, and Q_{VCS} is computed (using the above equation for Q_{VCS}), with the head value

$$h_{VCS} = \frac{E_{VCS} + E_{RCS}}{2} - E_{PermPool}$$

From the stage-storage table, find the elevation associated with RCS. The average head on the RCS outlet can then be calculated as:

$$h_{RCS_avg} = \frac{E_{RCS} - E_{VCS}}{2}$$

Again, the required orifice cross sectional area can then be indirectly computed using the orifice equation:

$$Q_{RCS} = CA_{RCS}\sqrt{2gh_{RCS}}$$

The diameter of the orifice is then

$$d_{RCS} = 2 \cdot \sqrt{\left(\frac{A_{RCS}}{\mathrm{p}}\right)}$$

The rate of discharge from the RCS orifice for any head value h_{RCS} on the RCS outlet can then be computed as:

$$Q_{RCS_avg} = CA_{RCS}\sqrt{2gh_{RCS_avg}}$$

The combined flow out of the volume control and rate control orifice at a given water surface elevation can be computed by adding together the discharges from the two structures, for the head values corresponding to the specified water surface elevation.

- Overbank flood control outlet: an outlet (typically a weir) with its invert at the RCS pool elevation, designed to release Qp10 at predevelopment rates (recommended).
- Extreme storm control outlet: an outlet with its invert at or slightly above the Overbank flood control pool elevation, designed to release Qp100 at predevelopment rates (recommended), or at minimum to safely pass the Qp100 with 1' of freeboard between the top of the embankment. Check with the city to determine whether a principal spillway can be used to manage extreme storm flows, or if an emergency spillway (broad-crested weir or earthen embankment, not susceptible to obstruction) is necessary.

Using the determined size information, incorporate the outlet structures into the pond design. Be aware of concerns associated with frozen conditions, particularly the risk of clogging or blockage of outlet structures with ice and the importance of burying pipes below the frost line. A skimmer or similar device is REQUIRED to prevent the discharge of floating debris.

<u>Step 9. Design spillway and embankments.</u>

The following items are some of the key guidelines to adhere to in the design of spillways and embankments.

- It is REQUIRED that the emergency overflow be stabilized.
- It is REQUIRED that embankments be overfilled by at least 5% to account for settling.

- The REQUIRED minimum embankment width is 6' (wider for embankment height >10' or if maintenance access will be required).
- It is REQUIRED that embankments be adequately stabilized with vegetation or other measures.
- It is HIGHLY RECOMMENDED that side slopes be no steeper than 3:1 (h:v).

Additional design guidance and requirements for spillways and embankments are found in NRCS Pond 378 Conservation Practice Standard for Minnesota, which is available at http://efotg.nrcs.usda.gov/references/public/MN/378mn.pdf.

Step 10. Design inlets.

To prevent freezing and blockage of inflow, it is HIGHLY RECOMMENDED that inlet pipes not be fully submerged and that they be buried below the frost line. Frost and thaw depths for several Minnesota sites are shown at the following website:
http://www.mrr.dot.state.mn.us/research/seasonal_load_limits/thawindex/frost_thaw_graphs.asp.

It is also HIGHLY RECOMMENDED to design the inlet to reduce or prevent scour, by including riprap or flow diffusion devices such as plunge pools or berms.

Step 11. Design sediment forebay

The size of the sediment forebay was determined in Step 5. It is RECOMMENDED that a sediment marker be included in the forebay to indicate the need for sediment removal in the future. A hard bottom surface in the forebay is also RECOMMENDED in order to make sediment removal easier.

As discussed in Step 6, a weir structure added to the forebay will ensure that some pretreatment storage is available, even when the normal forebay is frozen.

Step 12. Check expected pond performance against regulatory requirements.

Check that V_{wq} is detained for an average of 12 hours.

Check that the V_{wq} release rate does not exceed 5.66 cfs/acre of pond area.

Determine applicable requirements for V_{cp} volume and release rate, and verify that the pond performs adequately for the appropriate design event.

Determine applicable requirements for Q_{p10} and Q_{p100} release rates (e.g., pre-development rates), and check pond release rates (and freeboard) for the appropriate design events.

Step 13. Design maintenance access and safety features.

Maintenance access to the pond, forebay, and inlet and outlet structures is REQUIRED. The access routes should be designed with a minimum 10' width and maximum 15% slope.

Safety features such as obstructive planting that make access difficult, signs warning against fishing and swimming, fencing, and grates over outlet structures should be included as appropriate.

Aesthetic enhancements such as trails or benches can also be included

If an outlet structure is greater than five feet deep, it is REQUIRED that OSHA health and safety guidelines be followed for safe construction and access practices. Additional information on safety for construction sites is available from OSHA. Use the following link to research safety measures for excavation sites:

http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10930

OSHA has prepared a flow chart which will help site owners and operators determine if the site safety plan must address confined space procedures:

Permit-required Confined Space Decision Flow Chart - 1910.146 App A

Step 14. Prepare vegetation and landscaping plan.

A landscaping and planting plan by a qualified professional for the pond and surrounding area should be prepared, utilizing native vegetation wherever possible.

Step 15. Prepare operation and maintenance plan.

Preparation of a plan for operation and maintenance of the pond and associated structures and landscaping is REQUIRED. The key issues related to pond O&M

Step 16. Prepare cost estimate.
Refer to the *Cost Considerations* section for information on preparing a cost estimate for stormwater ponds.

F. Links to Other Manuals

The following links connect to information about wet extended detention ponds contained in other stormwater manuals.

Georgia Stormwater Management Manual
http://www.georgiastormwater.com/vol2/3-2-1.pdf

Idaho Department of Environmental Quality
http://www.deq.state.id.us/water/stormwater_catalog/doc_bmp47.asp

Maryland Department of the Environment
http://www.mde.state.md.us/assets/document/chapter3.pdf

Metropolitan Council
http://www.metrocouncil.org/environment/Watershed/BMP/CH3_STRetenExtended.pdf

Minnesota Pollution Control Agency
http://www.pca.state.mn.us/water/pubs/swm-ch5.pdf

New Jersey Department of Environmental Protection
http://www.njstormwater.org/tier_A/pdf/NJ_SWBMP_9.4%20print.pdf

New York State Dept. of Environmental Conservation
http://www.dec.state.ny.us/website/dow/swmanual/chapter6.pdf

U.S. Dept of Transportation Federal Highway Administration
http://www.fhwa.dot.gov/environment/ultraurb/3fs4.htm

Vermont Water Quality Division
http://www.anr.state.vt.us/dec/waterq/stormwater/docs/sw_manual-vol1.pdf

Western Washington
http://www.ecy.wa.gov/pubs/9915.pdf

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STORMWATER WETLANDS

Stillwater, MN

Definition:
Constructed wetlands systems are used to store and treat runoff by mimicking the function of natural wetlands. However, stormwater wetlands are not natural wetlands and should not be included in natural wetland areas.

KEY CONSIDERATIONS

Design Criteria:

- A water budget should be calculated to ensure proper drainage area and to ensure that wetland conditions can be maintained.
- A minimum length to width ratio of 2:1 should be maintained during low flow or baseflow conditions.
- A minimum of 35% of the total wetland surface area should have a depth of 6 inches or less; 10% to 20% of surface area should be deep pool (1.5 to 6 foot depth).
- Constructed wetlands require about 2% to 4% of the area that drains to them.
- Thermal effects of discharged waters from stormwater wetlands on receiving bodies of water should be considered.

Benefits:

- Good suspended solid and annual nutrient removal
- Provides good wildlife habitat and aesthetic value
- Low maintenance costs
- Provides ground water: surface-water interface

Limitations:

- Requires more land than other practices
- Requires careful design and planning to ensure wetland hydrology is maintained
- Water quality behavior can change seasonally

MANAGEMENT SUITABILITY

	Volume Control
X	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
X	Wetland Bounce

MECHANISMS

	Infiltration
X	Screening/ Filtration
	Temperature Control
X	Settling
X	Evaporation
X	Transpiration
X	Soil Adsorption
X	Biological/ Micro. Uptake

POLLUTION REMOVAL

75%	Total Suspended Solids
40%	Nutrients - Total Phosphorus/ Total Nitrogen
40%	Metals - Cadmium, Copper, Lead, and Zinc
75%	Pathogens - Bacteria
85%	Toxins - Hydrocarbon

SITE FACTORS

10-25 AC Min	Drainage Area *small applications may require only 5 acres of drainage area
25%	Max. Slope
3' Min*	Min. Depth to Bedrock *if above water supply aquifer or treating hotspots
3' Min*	Min. Depth to Seasonally High Water Table *if above water supply aquifer or treating hotspots
A,B,C,D	NRCS Soil Type
Good	Freeze/ Thaw Suitability
Yes	Potential Hotspot Runoff *requires impermeable liner

Description:
Stormwater wetlands are constructed shallow marsh systems designed to treat stormwater and, to a lesser extent, control runoff volumes in urban environments. Stormwater wetlands are different from natural systems in that they are specifically designed and constructed for the purpose of managing stormwater runoff. Like natural wetlands, stormwater wetlands require adequate hydrologic input to properly function. Water treatment is achieved through settling of particulates in the wetland system and uptake of nutrients and other constituents in the water by vegetation, soil, and biota. Stormwater wetlands can be very effective at removing pollutants and offer additional benefits in terms of aesthetics, ground water interaction, and wildlife and vegetative habitat.

Stormwater wetlands are best suited to removing contaminants other than sediment from flow. If sediment loads are high, pre-treatment is required. Pre-treatment options include the use of sediment forebays, filter strips, and construction of a pond upstream of the wetland to remove sediment. The choice of a particular pre-treatment option depends on site and hydrologic conditions.

Stormwater wetlands are often termed constructed, artificial, man-made, and engineered wetlands.

Design Variations and Schematics:
There are three (3) basic types of stormwater wetlands: 1) shallow wetland, 2) extended detention (ED) shallow wetland, and 3) pond/wetland systems. Each basic design prescribes different amounts of shallow and deep water and amount of dry storage above the wetland. Following is a brief description of the three major types of stormwater wetlands:

Shallow Wetland – A shallow wetland is designed with different areas of shallow and relatively deeper marsh. The deeper portions of the marsh are located at the sediment forebay at the wetland inlet and the micropool at the wetland's outlet. Shallow wetlands can be designed for smaller drainage areas (5 – 10 acres) though excavation to the water table may be required to sustain wetland hydrology.

Extended Detention (ED) Shallow Wetland – The ED shallow wetland design incorporates additional water quality treatment detention above the surface of the shallow wetland design. The additional storage area is typically designed to dewater in a period of 24 hours so that vegetation is not damaged. This design requires a smaller project footprint than the shallow wetland system because temporary vertical storage is substituted for shallow marsh storage, though water quality treatment may be reduced as residence time and contact time with vegetation is also likely to diminish.

Pond/Wetland Systems – This design incorporates a shallow marsh and wet pond to achieve water quality and quantity goals. Stormwater flows into the wet pond first, where sediments and sediment-bound pollutants have the opportunity to settle out and water velocities are reduced before entering the shallow marsh area. Less land is generally required for the pond/wetland system than for either the shallow wetland or ED shallow wetland designs.

A. Suitability

General

Stormwater wetlands are similar in design to stormwater ponds and mainly differ by their variety of water depths and associated vegetative complex. They require slightly more surface area than stormwater ponds for the same contributing drainage area. Stormwater wetlands are constructed stormwater management practices, not natural wetlands. Like ponds, they can contain a permanent pool and temporary storage for water quality control and runoff quantity control.

Wetlands are widely applicable stormwater treatment practices that provide both water quality treatment and water quantity control. Stormwater wetlands are best suited for drainage areas of at least 10 acres. When designed and maintained properly, stormwater wetlands can be an important aesthetic feature of a site.

Function Within Stormwater Treatment Train

Stormwater wetlands are typically installed at the downstream end of the treatment train (they are considered an end-of-pipe BMP). Stormwater wetland size and outflow regulation requirements can be significantly reduced with the use of additional upstream BMPs. However, when a stormwater wetland is constructed, it is likely to be the only management practice employed at a site, and therefore must be designed to provide adequate water quality and water quantity treatment for all regulated storms.

Inver Grove Heights Permit Applicability

One of the goals of this manual is to facilitate an understanding of and compliance with the city of Inver Grove Heights' Volume Control Standard. This standard must be met on all new and re-development projects taking place in the northwest area.

Stormwater wetlands generally may be used to meet the Inver Grove Heights pretreatment requirements. (Chapter 6) Stormwater wetland systems that incorporate infiltration may also reduce the 5-year 24-hour infiltration standard by the amount that the practice is able to store and infiltrate.

The following terms are thus used in the text to distinguish various levels of green roof design guidance:

REQUIRED:	Indicates design standards stipulated by the IGH PUD.
HIGHLY RECOMMENDED:	Indicates design guidance that is extremely beneficial or necessary for proper functioning of the practice, but is not specifically required by the City of Inver Grove Heights.
RECOMMENDED:	Indicates design guidance that is helpful for performance but not critical to the design.

Design Variants

Stormwater wetlands are constructed with varying amounts of the following three components:

- Shallow marsh area
- Permanent micropool area
- Storage volume above the normal water level

The amount of each of the components named above depends on the desired type of stormwater wetland (e.g., shallow wetland).

Stormwater wetland design must be tailored to site characteristics; however, some general RECOMMENDED design criteria for shallow wetland, ED shallow wetland, and pond/wetland design are presented in Table 8.41.

Table 8.41 Stormwater wetland general design criteria

Design Criteria	Shallow Wetland	Pond/Wetland	ED Shallow Wetland[1]
Wetland/Watershed Ratio	0.2	0.1	0.1
Minimum Drainage Area	25	10	25
Length to Width Ratio (minimum)	2:1	2:1	2:1
Extended Detention (ED)	No	Optional	Yes
Allocation of Permanent Pool Volume (pool/marsh/ ED) in %	25/75/0	70/30/0 (includes pond volume)	25/25/50
Allocation of Surface Area (deepwater/low marsh/ high marsh/semi-wet) in %	20/35/40/5	45/25/25/5 (includes pond surface area)	10/35/45/10
Forebay	Required	Required	Required
Micropool	Required	Required	Required
Outlet Configuration	Reverse-slope pipe or hooded broad-crested weir	Reverse-slope pipe or hooded broad-crested weir	Reverse-slope pipe or hooded broad-crested weir

Note: The ED Shallow Wetland design guidance does not meet the MPCA requirements for permanent volume. The guidance may be applied in a stormwater retrofit situation where area requirements preclude the use of a Shallow Wetland.

The proportion of deep water, low marsh, high marsh, and semi-wet marsh is presented above in Table 8.41 and are defined as:

- ***Deepwater zone*** – From 1.5 to 6 feet deep. Includes the outlet micropool and the deepwater channels through the wetland facility. This zone supports little emergent wetland vegetation but may support submerged or floating vegetation.
- ***Low marsh zone*** – From 6 to 18 inches below the normal permanent pool or water surface elevation. This zone is suitable for the growing of several emergent wetland plant species.
- ***High marsh zone*** – From 6 inches below the pool to the normal pool elevation. This zone will support a greater density and diversity of wetland species than the low marsh zone. The high marsh zone should have a higher surface area to volume ratio than the low marsh zone.
- ***Semi-wet zone*** – Those areas above the permanent pool that are inundated during larger storm events. This zone supports a number of species that can survive flooding.

Retrofit Suitability

As a retrofit, stormwater wetlands have the advantage of providing both educational and habitat value. One disadvantage of wetlands, however, is the difficulty in storing large amounts of runoff without consuming a large amount of land. Therefore, the most common type of wetland retrofit involves the modification of an existing dry or wet pond.

Cold Climate Suitability

Wetland performance can be decreased in spring months when large volumes of runoff occur in a relatively short time carrying the accumulated pollutant load from the winter months. Because stormwater wetlands are relatively shallow, freezing of the shallow pool can occur. Also, freezing of inlet and outlet structures can occur, which will reduce performance of the stormwater wetland. To avoid these problems, the CWP (Caraco and Claytor, 1997) made some general design suggestions, which are adapted as follows:

- Inlet pipes should not be submerged, since this can result in freezing and upstream damage or flooding.
- Burying all pipes below the frost line can prevent frost heave and pipe freezing. Wind protection can also be an important consideration for pipes above the frost line. In these cases, designs modifications that have pipes “turn the corner” are helpful.
- Increase the slope of inlet pipes to a minimum of 1% to prevent standing water in the pipe, reducing the potential for ice formation. This design may be difficult to achieve at sites with flat local slopes.
- If perforated riser pipes are used, the minimum opening diameter should be ½”. In addition, the pipe should have a minimum 6” diameter.
- When a standard weir is used, the minimum slot width should be 3", especially when the slot is tall.
- Baffle weirs can prevent ice reformation during the spring melt near the outlet by preventing surface ice from blocking the outlet structure.
- In cold climates, riser hoods should be oversized and reverse slope pipes should draw from at least 6" below the typical ice layer.
- Alternative outlet designs that have been successful include using a pipe encased in a gravel jacket set at the elevation of the aquatic bench as the control for water quality events. This practice was both avoids stream warming and is also a non-freezing outlet.
- Trash racks should be installed at a shallow angle to prevent ice formation.

Water Quantity Treatment

Stormwater wetlands are well-suited to meet the rate control standard (RCS) and act as pretreatment for the volume control standard (VCS). As in ponds, this is accomplished with live storage (extended detention) above the permanent pool. It is HIGHLY RECOMMENDED that when providing water quantity control in stormwater wetlands, the smallest possible bounce (vertical water level fluctuation) be sought, in order to limit the amount of stress on the vegetation.

Water Quality Treatment

Pollutants are removed from stormwater runoff in a wetland through uptake by wetland vegetation and biota (algae, bacterial), vegetative filtering, soil adsorption, and gravitational settling in the slow moving marsh flow. Volatilization and chemical activity can also occur, breaking down and assimilating a number of other stormwater contaminants such as hydrocarbons.

Pollutant removal efficiencies and optimum effluent concentrations for select parameters are provided in Tables 8.42 and 8.43, respectively.

Table 8.42 Percent Removal of Key Pollutants

Practice	TSS [%]	Total Phosphorus [%]	Total Nitrogen [%]	Metals[1] [%]	Bacteria [%]	Hydro-carbons [%]
Stormwater Wetlands	76	49	30	42	78[2]	85[2]

1. Average of zinc and copper.
2. Based on fewer than five data points (i.e., independent monitoring studies)

Removals represent median values from Winer (2000)

Table 8.43 Typical BMP Best Attainable Effluent Concentrations					
Practice	TSS [mg/l]	TP [mg/l]	TN [mg/l]	Cu [ug/l]	Zn [ug/l]
Wetlands	6	0.2	1.7	3.0	50
Values from ASCE bmp database and Winer 2000					

Limitations

The following general limitations should be recognized when considering installation of stormwater wetlands:

- they require more land than other practices
- they require careful design and planning to ensure wetland hydrology is maintained
- water quality behavior can change seasonally

B. Major Design Elements

Physical Feasibility Initial Check

Before deciding to construct a wetland for stormwater management, it is helpful to consider several items that bear on the feasibility of using a wetland at a given location. The following list of considerations will help in making an initial judgment as to whether or not a wetland is the appropriate BMP for the site.

- ***Drainage Area*** – 25 acres minimum HIGHLY RECOMMENDED, ensuring hydrologic input sufficient to maintain permanent pool; 10 acres (or less) may be acceptable, particularly if the groundwater table is intercepted and a water balance indicates that a permanent pool can be sustained.
- ***Space Required*** – Approximately 2-4% of the tributary drainage area is RECOMMENDED for wetland footprint.
- ***Minimum Head*** – The elevation difference RECOMMENDED at a site from the inflow to the outflow is 6-10 feet.
- ***Minimum Depth to Water Table*** – In general, there is no minimum separation distance required with stormwater wetlands. In fact, intercepting the groundwater table is common and helps sustain a permanent pool. However, some source water protection requirements may dictate a separation distance if there is a sensitive underlying aquifer, which means that a liner might be required for portions of the wetland with standing water.
- ***Soils*** – Underlying soils of hydrologic group “C” or “D” should be adequate to maintain a permanent pool. Most group “A” soils and some group “B” soils will require a liner. A site specific geotechnical investigation should be performed. Also, if earthen embankments are to be constructed, it will be necessary to use suitable soils.
- ***Groundwater Protection*** –It is REQUIRED that stormwater wetlands treating runoff from PSHs provide excellent treatment capabilities. In some cases (depending on the land use and associated activities), lining the stormwater wetland may be necessary to protect groundwater, particularly when the seasonally high groundwater elevation is within three feet of the practice bottom.

Conveyance

Inflow Points

- It is HIGHLY RECOMMENDED that inlet areas be stabilized to ensure that non-erosive conditions exist during events up to the design event. It is HIGHLY RECOMMENDED that inlet pipe inverts be located at the permanent pool elevation. Submerging the inlet pipe is can result in freezing and upstream damage.
- It is HIGHLY RECOMMENDED that inlet pipes have a slope of no flatter than 1%, to prevent standing water in the pipe and reduce the potential for ice formation.
- It is HIGHLY RECOMMENDED that pipes be buried below the frost line, to prevent frost heave and pipe freezing.
- It is HIGHLY RECOMMENDED that where open channels are used to convey runoff to the wetland, the channels be stabilized to reduce the sediment loads.

Adequate Outfall Protection

Stormwater wetland outfalls should be designed to not increase erosion or have undue influence on the downstream geomorphology of the stream.

- It is HIGHLY RECOMMENDED that a stilling basin or outlet protection be used to reduce flow velocities from the principal spillway to non-erosive velocities (3.5 to 5.0 fps).
- Flared pipe sections that discharge at or near the stream invert or into a step-pool arrangement are RECOMMENDED over headwalls at the spillway outlet.
- It is RECOMMENDED that tree clearing be minimized along the downstream channel and that a forested riparian zone be reestablished in the shortest possible distance. It is also RECOMMENDED that excessive use of riprap be avoided, to minimize stream warming in channels with dry weather flow.
- Local agencies (Watershed Districts, Watershed Management Organizations (WMOs), municipalities, etc.) may have additional outlet control requirements.

Pretreatment

Sediment forebays are the RECOMMENDED pretreatment method for stormwater wetlands, although other features, such as grassed swales, could be used to remove sediment from runoff before it enters the wetland system. A forebay or equivalent pretreatment should be in place at each inlet to ease the maintenance burden and preserve the longevity of the stormwater wetland. See the section on Stormwater Ponds for design guidance.

Treatment

Permanent Pool and Volume Control Standard (VCS)

Stormwater wetlands follow similar sizing criteria as stormwater ponds. See the Stormwater Ponds section for guidance on sizing the permanent pool volumes, volume control standard volume, and depth.

A water balance is recommended to document sufficient inflows to maintain a constant wetland pool and sustain wetland vegetation during prolonged dry weather conditions. This is of particular importance in stormwater wetlands. The basic approach to performing a water balance is as follows:

1. Check maximum drawdown during periods of high evaporation and during an extended period of no appreciable rainfall to ensure that wetland vegetation will survive.
2. The change in storage within a wetland = inflows – outflows.
3. Potential inflows: runoff, baseflow and rainfall.
4. Potential outflows: infiltration, surface overflow and evapotranspiration
5. Assume no inflow from baseflow, no outflow losses for infiltration and because only the permanent pool volume is being evaluated, no outflow losses for surface overflows. The validity of these assumptions need to be verified for each design.
6. Therefore, storage = runoff - evaporation

If a liner is required for the stormwater wetland, it should be designed following the same guidance as for stormwater ponds.

Grading and Site Layout

Site layout and grading affect the pollutant removal capability of the stormwater wetlands as well as the ease of maintenance. Performance is enhanced when multiple cells, longer flowpaths, high surface area to volume ratios, and complex microtopography are used. Specific design considerations for site layout include:

- It is RECOMMENDED that the minimum length to width ratio for ponds be 2:1.
- It is RECOMMENDED that to the greatest extent possible, stormwater wetlands be irregularly shaped and long flow paths be maintained.
- Microtopography (small irregular 6 to 24 inch variations in bottom topography) is RECOMMENDED to enhance wetland diversity.
- It is HIGHLY RECOMMENDED that at least 25% of the wetland pool volume of a stormwater wetland be in deepwater zones with a depth greater than four feet.
- It is HIGHLY RECOMMENDED that a minimum of 35% of the total surface area of stormwater wetlands should have a depth of six inches or less, and at least 65% of the total surface area shall be shallower than 18 inches.
- It is HIGHLY RECOMMENDED that a micropool be excavated at the pond outlet to prevent resuspension of sediments.
- It is HIGHLY RECOMMENDED that the extended detention associated with the VCS and RCS not extend more than three feet above the permanent pool at its maximum water surface elevation.
- It is HIGHLY RECOMMENDED that berms be used to separate wetland cells. This reduces the incidence of freezing and requires less maintenance than pipes or concrete weirs.
- Structures such as fascines, coconut rolls, straw bales, or carefully designed stone weirs can be used to create shallow marsh cells in high-energy areas of the stormwater wetland.
- It is HIGHLY RECOMMENDED that the perimeter of all deep pool areas (four feet or greater in depth) be surrounded by a safety bench and aquatic bench, as described in the stormwater ponds section. The aquatic benches can be incorporated into the pond microtopography.

Landscaping

Landscaping Plan

There are many references describing suitable native species of plants for Minnesota. The reader is referred to the Appendix B as well as to Shaw, D. and R. Schmidt. 2003. Plants for Stormwater Design. Minnesota Pollution Control Agency, St. Paul, MN. The following guidelines are RECOMMENDED for landscaping of stormwater wetland facilities.

- A landscaping plan shall be provided that indicates the methods used to establish and maintain wetland coverage. Minimum elements of a plan include: delineation of pondscaping zones, selection of corresponding plant species, planting plan, sequence for preparing wetland bed (including soil amendments, if needed) and sources of plant material.
- Vegetation selection should be based on the anticipated hydrologic function of the stormwater wetland (e.g. water level fluctuation).
- Design should consider control – predation by carp, geese, deer, etc.
- Donor soils for stormwater wetland mulch should not be removed from natural wetlands.
- Wetland soils mix often contain wetland plant propagules that help to establish the plant community.
- The landscaping plan should provide elements that promote greater wildlife and waterfowl use within the stormwater wetland and buffers.
- The planting schedule should reflect the short growing season. Designers should consider incorporating relatively mature plants, or planting dormant rhizomes during the winter.

- If a minimum coverage of 50% is not achieved in the planted wetland zones after the second growing season, a reinforcement planting is required.
- It is RECOMMENDED that a landscape architect or another landscape professional be consulted in selection of wetland plants.

Safety

- It is REQUIRED that public safety be considered in every aspect of stormwater wetland design.
- The principal spillway opening should not permit access by small children, and endwalls above pipe outfalls greater than 48 inches in diameter should be fenced to prevent a hazard.
- The access and aquatic benches should be landscaped to prevent access to the wetland.
- Warning signs prohibiting swimming, skating, and fishing should be posted.
- Wetland fencing is generally not encouraged, but may be required by some municipalities. A preferred method is to grade the pond to eliminate steep drop-offs or other safety hazards.
- Dam safety regulations should be strictly followed with stormwater wetland design to ensure that downstream property and structures are adequately protected.

C. Construction Details and Specifications

CADD based details for pond systems are contained in Appendix A. The following details, with specifications, have been created for stormwater ponds/wetlands:

- Extended Detention Shallow Wetland Plan
- Extended Detention Shallow Wetland Profile
- Outlet Structures

D. Operation and Maintenance

Overview

Maintenance is necessary for a stormwater wetland to operate as designed on a long-term basis. The pollutant removal capabilities of stormwater wetlands will decrease if:

- Wetland pool elevations fluctuate dramatically
- Debris blocks the outlet structure
- Pipes or the riser are damaged
- Invasive plants out-compete the wetland plants
- Sediment accumulates in the stormwater wetland, reducing the storage volume
- Slope stabilizing and desirable wetland vegetation is lost
- The structural integrity of the embankment, weir, or riser is compromised.

Stormwater wetland maintenance activities range in terms of the level of effort and expertise required to perform them. Routine stormwater wetland maintenance, such as mowing and removing debris or trash, is needed multiple times each year, but can be performed by citizen volunteers. More significant maintenance, such as removing accumulated sediment, is needed less frequently but requires more skilled labor and special equipment. Inspection and repair of critical structural features such as embankments and risers, needs to be performed by a qualified professional (e.g., structural engineer) that has experience in the construction, inspection, and repair of these features.

Design Phase Maintenance Considerations

Implicit in the design guidance in the previous sections, many design elements of stormwater wetland systems can minimize the maintenance burden and maintain pollutant removal efficiency. Primarily, providing easy access (typically 8 feet wide) to stormwater wetlands for routine maintenance is REQUIRED.

Mosquito control is of particular concern in the case of stormwater wetlands. They can be properly designed, constructed and maintained to minimize the likelihood of being desirable habitat for mosquito populations. Designs that incorporate constant inflows and outflows, habitat for natural predators, and constant permanent pool elevations limit the conditions typical of mosquito breeding habitat. See Chapter 6 for an in-depth discussion of mosquito concerns in stormwater management.

Construction Phase Maintenance

The construction phase is another critical step where O&M issues can be minimized or avoided. Inspections during construction are needed to ensure that the stormwater wetland is built in accordance with the approved design and standards and specifications. Detailed inspection checklists should be used that include sign-offs by qualified individuals at critical stages of construction, to ensure that the contractor's interpretation of the plan is acceptable to the professional designer. An example construction phase inspection checklist is provided in Appendix D.

Post Construction Operation and Maintenance

Some important post construction maintenance considerations are provided below. A more detailed checklist of maintenance activities and associated schedules is provided in Appendix D. More detailed maintenance guidance can be found in the Pond and Wetland Maintenance Guidebook (CWP, 2004).

- It is REQUIRED that a legally binding and enforceable maintenance agreement be executed between the practice owner and the city of Inver Grove Heights.
- Adequate access must be provided for inspection, maintenance, and landscaping upkeep, including appropriate equipment and vehicles. It is RECOMMENDED that a maintenance right of way or easement extend to ponds from a public or private road.
- It is HIGHLY RECOMMENDED that stormwater wetlands be inspected annually during winter freeze periods to look for signs of improper operation.
- It is HIGHLY RECOMMENDED that sediment removal in the forebay occur every 2 to 7 years or after 50% of total forebay capacity has been lost. In areas where road sand is used, an inspection of the forebay and stormwater wetland should be scheduled after the spring melt to determine if clean-out is necessary.
- Sediments excavated from stormwater wetlands that do not receive runoff from confirmed hotspots are generally not considered toxic or hazardous material, and can be safely disposed by either land application or land filling. Sediment testing may be necessary prior to sediment disposal when a confirmed hotspot land use is present.
- Periodic mowing of the stormwater wetland buffer is HIGHLY RECOMMENDED along maintenance rights-of-way and the embankment. The remaining buffer can be managed as a meadow (mowing every other year), prairie, or forest.
- General maintenance activities and schedule are provided in Table 8.44.

Table 8.44 Typical Inspection/Maintenance Frequencies for Stormwater Wetlands

Inspection Items	Maintenance Items	Frequency
► Ensure that at least 50% of wetland plants survive ► Check for invasive wetland plants	► Replant wetland vegetation	One time - After First Year
► Inspect low flow orifices and other pipes for clogging ► Check the permanent pool or dry pond area for floating debris or undesirable vegetation ► Investigate the shoreline for erosion ► Monitor wetland plant composition and health ► Look for broken signs, locks, and other dangerous items	► Mowing – minimum Spring and Fall ► Remove debris ► Repair undercut, eroded, and bare soil areas	Monthly to Quarterly or After Major Storms (>1")
► Monitor wetland plant composition and health ► Identify invasive plants ► Assure mechanical components are functional	► Trash and debris clean-up day ► Remove invasive plants ► Harvest wetland plants ► Replant wetland vegetation ► Repair broken mechanical components if needed	Semi-annual to annual
► All routine inspection items above ► Inspect riser, barrel, and embankment for damage ► Inspect all pipes ► Monitor sediment deposition in facility and forebay	► Pipe and Riser Repair ► Forebay maintenance and sediment removal when needed	Every 1 to 3 years
► Monitor sediment deposition in facility and forebay	► Forebay maintenance and sediment removal when needed	2-7 years or 50% loss of sediment forebay storage
► Remote television inspection of reverse slope pipes, underdrains, and other hard to access piping	► Sediment removal from main pond/wetland ► Pipe replacement if needed	5-25 years

Cost Considerations

Cost factors for stormwater management ponds are extremely sensitive to site conditions. Availability of in situ materials for embankment construction, outlet protection, cost of excavation, liner materials, and land costs are significant factors. Maintenance and inspection costs for mowing and periodic dredging are post-development factors. Other technologies such as infiltration trenches may be more cost-effective in smaller drainage areas due to construction and long-term maintenance costs (Young et al., 1996). Costs for ponds typically include costs for embankment, riser and spillway structures, outfall protection, vegetative stabilization, excavation, and grading. Additional costs for site preparation can include soil amendments, precision grading, plant materials and creation of occluding layers in coarse-textured soil types if wetlands systems must be created on upland sites due to project constraints. Project costs can be lowered if existing pre-construction site conditions are carefully considered and isolated areas with hydric soils contained within the footprint of the project are utilized as stormwater management facilities.

Additional maintenance costs will be incurred until the establishment of the wetland ecosystem. Invasive plants must be culled and dead plants replaced. The outlet structure may have to be adjusted, based on seasonal observations, to achieve the proper water surface in the pond. (FHWA Ultra Urban BMP Manual).

Detailed Cost Estimate

The most appropriate technique for determining the cost to construct and maintain a specific BMP will be to apply unit costs to each component of construction, operation and/or maintenance. Table 8.45 represents the typical components for stormwater wetlands. This table presents those components of a construction project that are unique to this Best Management Practice. Costs that would be associated with all aspects of a construction site, such as erosion and sediment control, mobilization, or traffic control, are not presented as unique costs.

Designers are encouraged to use the cost worksheet included in Appendix F to estimate their BMP construction cost.

Table 8.45 Typical components of stormwater wetlands

Implementation Stage	Primary Cost Components	Basic Cost Estimate	Other Considerations
Site Preparation	Tree & plant protection	Protection Cost ($/acre) x Affected Area (acre)	Removal of existing structures, topsoil removal and stockpiling
	Topsoil salvage	Salvage Cost ($/acre) x Affected Area (acre)	
	Clearing & grubbing	Clearing Cost ($/acre) x Affected Area (acre)	
Site Formation	Excavation / grading	4-ft Depth Excavation Cost ($/acre) x Area (acre)	Soil & rock fill material, tunneling
	Hauling material offsite	Excavation Cost x (% of Material to be hauled away)	
Structural Components	Inlet structure	($/structure)	Pipes, catchbasins, manholes, valves
	Outlet structure	($/structure)	

Table 8.45 Typical components of stormwater wetlands			
Implementation Stage	**Primary Cost Components**	**Basic Cost Estimate**	**Other Considerations**
Site Restoration	Soil Preparation	Soil cost ($/acre) x Seeding/ planting area (1 ft average depth per acre)	Tree protection, soil amendments, seed bed preparation, trails
	Seeding (or sodding)	Seeding Cost ($/acre) x Seeded Area (acre)	
	Planting / transplanting	Planting Cost ($/acre) x Planted Area (acre)	
Annual Operation, Maintenance, and Inspection	Debris removal	Removal Cost ($/acre) x Area (acre) x Frequency (2 / 1yr)	Vegetation maintenance, cleaning of structures
	Invasive plant removal	Labor Cost ($/hr) x Time x Frequency	
	Sediment removal	Removal Cost ($/acre) x Area (acre) x Frequency (1 / 5yr)	
	Erosion Repair	Repair cost ($/area) x Area Affected	
	Gate / valve operation	Operation Cost ($) x Operation Frequency (2 / 1 yr)	
	Inspection	Inspection Cost ($) x Inspection Frequency (2 / 1 yr)	
	Mowing	Mowing Cost ($) x Mowing Frequency (4 / 1 yr)	

E. Design Procedure

The following steps outline a recommended design procedure for a wet extended detention pond (wet sedimentation basin) in compliance with the Inver Grove Heights Stormwater Permit. Design recommendations beyond those specifically required by the permit are also included and marked accordingly.

Step by Step Design Procedure:

<u>Step 1. Make a preliminary judgment as to whether site conditions are appropriate for the use of a stormwater wetland, and identify the function of the wetland in the overall treatment system</u>

A. Consider basic issues for initial suitability screening
- ► Site drainage area
- ► Soils
- ► Slopes
- ► Space required for wetland

- Depth to water table
- Minimum head
- Receiving waters

B. Determine how the wetland will fit into the overall stormwater treatment system
   - Are other BMPs to be used in concert with the constructed wetland?
   - Will a pond be part of the wetland design and if so, where?

Step 2. Confirm local design criteria and applicability

A. Determine whether the wetland must comply with the MPCA Permit.
B. Check with Inver Grove Heights officials and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 3. Confirm site suitability

A. Perform field verification of site suitability.
   - If the initial evaluation indicates that a pond would be a good BMP for the site, it is RECOMMENDED that a sufficient number of soil borings should be taken to ensure wetland conditions (hydrologic and vegetative) can be maintained after construction. The number of borings will vary depending on size of the site, parent material and design complexity. For example, a design that requires compacted earth material to form a dike will likely require more borings than one without this feature.
   - It is RECOMMENDED that the soil borings or pits be five feet below the bottom elevation of the proposed stormwater wetland.
   - It is HIGHLY RECOMMENDED that the field verification be conducted by a qualified geotechnical professional.

B. Perform water balance calculations if needed.

Step 4. Compute runoff control volumes and permanent pool volume.

If the pond is being designed as a wet detention pond for new construction under the MPCA Permit, then a permanent pool volume equal to 1800 cubic feet for each acre draining to the pond is REQUIRED. This can be calculated as:

$$\text{Permanent Pond Volume} = 1800\left[\frac{ft^3}{Ac}\right] * A\left[Ac\right] \text{ [ft3]}$$

If part of the overall VCS is to be treated by other BMPs, subtract that portion from the VCS to determine the part of the VCS to be treated by the pond. It is assumed that the pond will be the only BMP used for rate control for larger storms.

Step 5. Determine pretreatment (sediment forebay) volume (HIGHLY RECOMMENDED)

In the absence of adequate upstream treatment by other BMPs, it is HIGHLY RECOMMENDED that a sediment forebay or similarly effective pretreatment system be provided at each inlet providing 10% or more of the total design inflow, with a RECOMMENDED volume equal to 10% of the permanent pool volume in a pool 4 to 6 feet deep. The forebay storage volume counts toward the total permanent pool requirement. Likewise, the storage volumes from other BMPs used upstream in the treatment train count toward the total permanent pool requirement and thus may be subtracted.

Step 6. Allocate the Permanent Pool volume among marsh, micropool, and ED volumes

Taking into consideration that 10% of the required volume has already been allocated to the pretreatment forebay or managed by some other BMP, the remaining 90% of the required volume may be allocated between marsh, micropool, and ED volumes using the recommendations presented in Table 8.41.

Volumes may be calculated as follows:

$$Vol_{pool} = 0.15 * (WP_v [ft^3])$$

$$Vol_{marsh} = 0.75 * (WP_v [ft^3])$$

$$Vol_{pool} = 0.15 * (WP_v [ft^3])$$

$$Vol_{marsh} = 0.25 * (WP_v [ft^3])$$

$$Vol_{ED} = 0.5 * (WP_v [ft^3])$$

Shallow Wetland:

Shallow ED Wetland:

Step 7. Determine wetland location and preliminary geometry, including distribution of wetland depth zones

This step involves initially laying out the wetland design and determining the distribution of wetland surface area among the various depth zones (high marsh, low marsh, and deep water). A stage-storage relationship should be developed to describe the storage requirements and to set the elevation of the wetland pool elevation, the volume control standard volume, the extended detention volume (if applicable), the rate control standard volume, etc.

The proportion of surface area to place in the various depth zones for each type of constructed wetland is shown in Table 8.41. Other guidelines for constructed wetland layout are:

- Provide maintenance access (8' width for trucks/machinery)
- Length to width ratios are presented in Table 8.41

Step 8. Compute extended detention orifice release rate(s), and establish Rate Control Standard (RCS) elevation

Shallow Wetland: The RCS elevation is determined from the stage-storage relationships and the orifice is then sized to release the RCS volume over a 24-hour period. The rate control orifice should have a minimum diameter of 3 inches and should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged 12 to 18 inches below the elevation of the wetland pool, or 6 inches below the normal ice depth, where outlet depths permit, is recommended. Adjustable gate valves can also be used to achieve these equivalent diameters.

1. The time period over which to release the RCS volume is typically 24 hours.

2. The release rate may then be calculated by:

$$Q_{VCS_avg} = \frac{VCS}{t_{WQ}} \quad \text{[cfs]}$$

where t_{VCS} is the time in seconds determined above. Check to determine if Q_{VCS} is less than or equal to 5.66 cfs per acre of surface area of the wetland. If Q_{VCS} meets the criterion, proceed to the next step in

the process. If Q_{VCS} is greater than 5.66 cfs, the release time should be increased or a two-stage outlet should be used whereby the first outlet is able to discharge VCS to meet the permit requirements. A two-stage outlet procedure is presented for the ED Shallow Wetland.

3. The average head is calculated as:

$$h_{vcs_avg} = \frac{Evcs - E_{PermPool}}{2} \text{ [ft]}$$

where E_{vcs} is the VCS pool elevation and $E_{PermPool}$ is the wetland pool elevation.

4. Given the design release rate, estimated in #2 above, an outlet may be sized using either the weir or orifice equations.

5. The discharge from the wetland can then be computed for any elevation between the RCS elevation and the wetland pool elevation.

ED Shallow Wetland: Based on the elevations established in Step 6 for the extended detention portion of the volume control standard volume, the water quality orifice is sized to release this extended detention volume in 24 hours. If a water quality orifice is used, it should have a minimum diameter of 3 inches, and should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged one foot below the elevation of the permanent pool, is a recommended design. Adjustable gate valves can also be used to achieve this equivalent diameter. The RCS elevation is then determined from the stage-storage relationship. The invert of the rate control standard orifice is located at the volume control extended detention elevation, and the structure outlet is sized to release the RCS volume over a 24-hour period.

Steps to compute the ED orifice are similar to those presented above for the Shallow Wetland. In this procedure VCS is equal to the extended detention volume.

1. The time period over which to release the VCS volume is typically 24 hours.

2. The release rate may then be calculated by:

$$Q_{VCS_avg} = \frac{VCS}{t_{VCS}} \text{ [cfs]}$$

where t_{VCS} is the time in seconds determined above in 2. Check to determine if Q_{VCS} is less than or equal to 5.66 cfs per acre of surface area of the wetland. If Q_{VCS} meets the criterion, proceed to the next step in the process. If Q_{VCS} is greater than 5.66 cfs, the release time should be increased.

3. The average head is calculated as:

$$h_{vcs_avg} = \frac{Evcs - E_{PermPool}}{2} \text{ [ft]}$$

where $Evcs$ is the elevation of the volume control standard water elevation and $E_{PermPool}$ is the wetland pool elevation.

4. Depending upon the outlet configuration, use the weir or orifice equation to calculate the outlet size.

5. The discharge from the wetland can then be computed for any elevation between the RCS elevation and the wetland pool elevation.

6. The release rate may then be calculated by:

$$Q_{RCS} = \frac{RCS\left[ft^3\right] - VCS\left[ft^3\right]}{t\left[s\right]} - Q_{VCS}(@\ RCS_v EL)$$

where t is the time in seconds determined above in 2. Check to determine if Q_{RCS} meets all design requirements.

6. The average head is calculated as:

$$h_{RCS_avg} = \frac{E_{RCS} - E_{VCS}}{2} \quad [ft]$$

where E_{RCS} is the elevation of the Rate Control Standard Volume and E_{VCS} is the Volume Control Standard Elevation

7. The orifice equation can then be used to calculate the orifice opening, A, as:

$$A_{RCS} = \frac{Q_{RCS}\left[cfs\right]}{C(2g[ft/s^2]h_{avg}[ft])^{0.5}} \quad [ft^2]$$

where g [ft/s/s] is the gravitational constant equal to 32.2 ft/s^2,
The discharge coefficient, C, can be conservatively estimated to be 0.6.

The diameter of the opening can then be solved for:

$$d_{RCS} = 2\left(\frac{A_{RCS}\left[ft^2\right]}{\pi}\right)^{0.5} \quad [ft]$$

8. The discharge from the wetland can then be computed for any elevation above the volume control standard elevation as:

$$Q_{RCS} = Kh^{0.5} \quad [cfs]$$

where $K = CA_{RCS}\,[ft](2g[\frac{ft}{s^2}])^{0.5}$ and $h = wse\,[ft] - E_{permpool}\,[ft] - d_{RCS}/2\,[ft]$

<u>Step 9. Design embankment(s) and spillway(s)</u>
For local stormwater management, size the emergency spillway for events larger than the 100-year 24-hour rainfall event. For regional stormwater management facilities, the design criteria for the emergency spillway can be found in the Overflow Contingency Plan.

At final design, provide safe passage for the 100-year event. Attenuation may not be required.

The following guidelines should also be followed (see NRCS Practice Standard 378 for further guidance):

- Embankments should be stabilized with vegetation (no trees) or riprap.
- Embankments may require a core-trench if geotechnical considerations warrant
- Embankment side slopes should not be steeper than 3H:1V on the front, 2H:1V on the back (impounded side).

- Minimum embankment top width is 6' (8' if equipment access is necessary)
- Material consolidation and shrinkage needs to be factored into embankment design
- Emergency overflows must be stabilized

Step 11. Design Inlets

To prevent freezing and associated blockage of the inflow, inlet pipes should not be completely submerged. It is also important to design the inlet to reduce or prevent scour, by including riprap or flow diffusion devices such as plunge pools or berms. To prevent standing water in the pipe, which reduces the potential for ice formation in the pipe, increase the slope to 1% if conditions permit.

Step 12. Design sediment forebay

It is recommended that a sediment marker be included in the forebay to indicate the need for sediment removal in the future. Also, a hard bottom surface in the forebay will make sediment removal easier, but note that a hard bottom surface will likely result in reduced vegetative and biotic processes that remove pollutants.

Step 13. Design outlet structures,

Be aware of concerns associated with frozen conditions, particularly the risk of clogging or blockage of outlet structures with ice.

- For weir structures, the minimum slot width should be 3".
- The minimum outlet pipe diameter should be 18", with a minimum slope of 1%.
- Outlet pipes should be buried below the frost line to the extent possible. Information on frost depths can be found from the Minnesota Department of Transportation at : http://www.mrr.dot.state.mn.us/research/seasonal_load_limits/thawindex/frost_thaw_graphs.asp
- If a riser pipe with an orifice outlet is used, the orifice should be protected by a hood that draws water from 12 to 18 inches below the normal wetland pool elevation, or 6" below the normal ice layer if known, if outlet site conditions permit.
- Trash racks should be installed at a shallow angle in order to discourage ice formation.
- A baffle weir or skimmer can be used to keep organic floatables in the wetland and prevent ice or debris from blocking the outlet.

Also, outlet pipes through the embankment should be equipped with an anti-seepage collar to prevent failure.

Step 14. Design maintenance access and safety features.

- Maintenance access to the pond, forebay, and inlet and outlet structures is REQUIRED. The access routes should be designed with a minimum 8' width and maximum 15% slope.
- Safety features such as obstructive planting that make access difficult, signs warning against fishing and swimming, fencing, and grates over outlet structures should be included as appropriate.
- Aesthetic enhancements such as trails or benches can also be included

Step 15. Prepare Vegetation and Landscaping Plan

See Major Design Elements for guidance on preparing vegetation and landscaping management plan.

Step 15. Prepare Operations and Maintenance (O&M) Plan

See Operations and Maintenance for guidance on preparing an O&M plan.

F. Links to Other Manuals

The following links connect to information about wet extended detention ponds contained in other stormwater manuals. Links to information about other types of ponds is not included here, because of their limited applicability in Minnesota.

Georgia Stormwater Management Manual
http://www.georgiastormwater.com/vol2/3-2-1.pdf

Idaho Department of Environmental Quality
http://www.deq.state.id.us/water/stormwater_catalog/doc_bmp47.asp

Maryland Department of the Environment
http://www.mde.state.md.us/assets/document/chapter3.pdf

Metropolitan Council
http://www.metrocouncil.org/environment/Watershed/BMP/CH3_STRetenExtended.pdf

Minnesota Pollution Control Agency
http://www.pca.state.mn.us/water/pubs/swm-ch5.pdf

New Jersey Department of Environmental Protection
http://www.njstormwater.org/tier_A/pdf/NJ_SWBMP_9.4%20print.pdf

New York State Dept. of Environmental Conservation
http://www.dec.state.ny.us/website/dow/swmanual/chapter6.pdf

U.S. Dept of Transportation Federal Highway Administration
http://www.fhwa.dot.gov/environment/ultraurb/3fs4.htm

Vermont Water Quality Division
http://www.anr.state.vt.us/dec/waterq/stormwater/docs/sw_manual-vol1.pdf

Western Washington
http://www.ecy.wa.gov/pubs/9915.pdf

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Center for Watershed Protection, 2004. *Stormwater Pond and Wetland Maintenance Guidebook*.

(FHWA Ultra Urban BMP Manual) "Ultra-Urban Best Management Practices." Federal Highway Administration, Washington, D.C., 1997 http://www.fhwa.dot.gov/environment/ultraurb/index.htm

Minnesota Climatology Working Group

MPCA, 2000. *Protecting Water Quality in Urban Areas*.

Natural Resources Conservation Service. Conservation Practice Standard 378, Pond.

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Winer, R. 2000. *National Pollutant Removal Performance Database*. Center for Watershed Protection, Ellicott City, MD.

Young, G Kenneth, Stuart Stein, Pamela Cole, Traci Kammer, Frank Graziano, Fred Bank. 1996. Evaluation and Management of Highway Runoff Water Quality. Office of Environment and Planning, Federal Highway Administration, Washington, D.C.

SOIL AMENDMENTS

Northwest Biosolids Management Association (2006)

Definition:
Soil amendments include a variety of soil impact minimization techniques that maintain or restore the impacts of grading on soil structure. The result of these practices is increased stormwater infiltration and filtration.

KEY CONSIDERATIONS

Design Criteria:

- Soil amendments should be used on graded sites to restore the pre-construction soil structure and encourage infiltration/filtration of stormwater.
- Identify the type of soil amendment to be used. Not disturbing native soils is the most cost-effective option, but is not always feasible.
- Amending soils with compost restores the organic matter of disturbed soils.

Benefits:

- Reduced stormwater runoff and associated infrastructure.
- Increased groundwater recharge
- Healthier vegetation

Limitations:

- Limited monitoring data are available
- Initial cost is higher than not amending soils, although savings from stormwater infrastructure can offset this cost
- Area must be fenced off from construction traffic after soils are amended.

MANAGEMENT SUITABILITY

X	Volume Control
X	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
X	Wetland Bounce

MECHANISMS

X	Infiltration
X	Screening/ Filtration
X	Temperature Control
	Settling
	Evaporation
X	Transpiration
X	Soil Adsorption
X	Biological/ Micro. Uptake

POLLUTION REMOVAL

NA	Total Suspended Solids
NA	Nutrients - Total Phosphorus/ Total Nitrogen
NA	Metals - Cadmium, Copper, Lead, and Zinc
NA	Pathogens - Bacteria
NA	Toxins - Hydrocarbon

SITE FACTORS

Any	Drainage Area
Any	Max. Slope
0 ft.	Min. Depth to Bedrock
0 ft.	Min. Depth to Seasonally High Water Table
Any	NRCS Soil Type
Good	Freeze/ Thaw Suitability
Yes	Potential Hotspot Runoff

Description:
Soil amendments can be subdivided into five categories (A-E)

A) Undisturbed Native Soil – Protect native soils from compaction during the construction phase.

B) Amend existing soils in-place – Where the soil has been compacted or the forest duff or topsoil removed, the simplest way to restore soil quality is to rototill compost into the existing soil.

C) Import topsoil mix– Where subsoil is too rocky, compacted or poorly drained to amend effectively; a topsoil mix with 8 – 13% soil organic matter can be imported and placed on the surface. “Manufactured” topsoil mixes should be weed free, making them ideal for seeding new lawns.

D) Native Soil: Stockpile site duff and topsoil; reapply after grading and construction – This design variant is only applicable to sites that have the original, undisturbed soil native to the site. This will most often be forested land that is being converted in the current project. Topsoil and forest duff excavated for structures and paved areas, or removed before site grading, can be stockpiled and reapplied after grading or other construction disturbances are completed. Stockpiling may not be practical on small sites.

E) Disturbed Soil: Stockpile topsoil, reapply and amend in place– This design variant is only applicable to sites where the soil is not the original, undisturbed soil native to the site. This will most often be unforested areas. Topsoil and forest duff excavated for structures and paved areas, or removed before site grading, can be stockpiled, reapplied after grading and amended.

A. Suitability

General

Healthy soil is vital to a clean environment and healthy landscapes. Deep soil that is rich in organic material absorbs and infiltrates rainwater, prevents flooding and soil erosion, and filters out pollutants typically associated with stormwater runoff. Healthy soil also stores water and nutrients for plants to use in dry times, promoting healthy plants that require less irrigation and pesticides.

Land development and landscaping practices can damage these valuable soil functions by removing or compacting topsoil. The result is decreased infiltration, increased erosion, unhealthy landscapes that are difficult and expensive to maintain, polluted water, impaired fish habitat, and increased need for stormwater management structures.

Ideally development projects should protect areas that aren't going to be constructed/altered by staking these areas. For areas that are altered as a result for the construction process the City of Inver Grove Heights recommends the use of soil amendments to restore soil functions. Developments are required to preserve topsoil, restore soils by adding compost after construction, or implement other measures to maintain the soil's moisture holding capacity. There are economical ways to retain the benefits of healthy soil, and avoid more costly damage to streams, wildlife, and human health.

Function Within Stormwater Treatment Train

Soil amendments are one of the first steps in the treatment train. Rain that falls on amended soils has a better chance to infiltrate or filter through the soil than on graded soils, thereby reducing runoff volume. The practice may be applied as part of a stormwater management system to achieve one of the following objectives:

- reduce stormwater pollutants
- increase groundwater recharge
- decrease runoff peak flow rates
- decrease the volume of stormwater runoff
- preserve base flow in streams
- reduce thermal impacts of runoff.

Inver Grove Heights Stormwater Permit Applicability

One of the goals of this manual is to facilitate an understanding of and compliance with the City of Inver Grove Heights' volume control standard. This standard must be met on all new and re-development projects taking place in the northwest area.

The Inver Grove Heights stormwater permitting process allows reduction of graded curve numbers for pervious areas that have been amended. When the post-construction CN is calculated, the Hydrologic Soil Group does not have to increase after development because the soil compaction impacts have been negated. This serves the function of reducing the applicant's proposed condition volume, reducing the volume of infiltration required to meet the 5-year pre-post condition infiltration requirement. Chapter 9 includes a detailed example of using soil amendments in calculating runoff.

The following terms are thus used in the text to distinguish various levels of soil amendment design guidance:

REQUIRED:	Indicates design standards stipulated by the IGH PUD.
HIGHLY RECOMMENDED:	Indicates design guidance that is extremely beneficial or necessary for proper functioning of the practice, but is not specifically required by the City of Inver Grove Heights.
RECOMMENDED:	Indicates design guidance that is helpful for performance but not critical to the design.

Design Variants

Undisturbed Native Soil – Protect native soils from compaction during the construction phase.

Amend existing soils in-place – Where the soil has been compacted or the forest duff or topsoil removed, the simplest way to restore soil quality is to rototill compost into the existing soil.

Import topsoil mix– Where subsoil is too rocky, compacted or poorly drained to amend effectively; a topsoil mix with 8 – 13% soil organic matter can be imported and placed on the surface. "Manufactured" topsoil mixes should be weed free, making them ideal for seeding new lawns.

Native Soil – Stockpile site duff and topsoil; reapply after grading and construction – This design variant is only applicable to sites that have the original, undisturbed soil native to the site. This will most often be forested land that is being converted in the current project. Topsoil and forest duff excavated for structures and paved areas, or removed before site grading, can be stockpiled and reapplied after grading or other construction disturbances are completed. Stockpiling may not be practical on small sites.

Disturbed Soil – Stockpile topsoil, reapply and amend in place– This design variant is only applicable to sites where the soil is not the original, undisturbed soil native to the site. This will most often be unforested areas. Topsoil and forest duff excavated for structures and paved areas, or removed before site grading, can be stockpiled, reapplied after grading and amended.

Retrofit Suitability

Whenever projects involve grading or landscaping; soil amendments are a good choice for the retrofit. For example, soils can be amended before an area is resodded, seeded or whenever the current vegetation is going to be removed. Soil amendments are particularly desirable as retrofit practices in watersheds or catchments that are targeting volume reduction practices.

Cold Climate Suitability

Soil amendments do not have cold climate design limitations.

Water Quantity Treatment

The amount of stormwater volume reduction depends on the quality and care of the amended area during construction. Soil amendments reduce runoff by increasing the permeability of the soil. This permeability of the soil can be most effectively maintained by planting deep-rooted vegetation.

In general, supplemental stormwater practices will be necessary to satisfy the volume control requirements when soil amendments are used. However, these practices can help reduce volume requirements for a site through volume reduction and retention.

Water Quality Treatment

Soil amendments improve water quality through stormwater volume reduction and increased groundwater recharge.

Limitations

The following general limitations should be recognized when considering soil amendments:

- Limited monitoring data are available
- Initial cost is higher than not amending soils, although savings from stormwater infrastructure can offset this cost
- Area must be fenced off from construction traffic after soils are amended.

B. Major Design Elements

Physical Feasibility Initial Check

All vegetated areas are recommended for soil amendments. Including lawns, landscaping, perennials, annuals, and native plantings.

Conveyance

Stormwater is conveyed by runoff and infiltration.

Pretreatment

Soil amendments require no pretreatment but grassed channels, filter strips, and bioretention areas may use amended soils as part of a pretreatment practice.

Treatment

Space Occupied – None, soil amendments are a space saving bmp that requires no additional space. Soil amendments reduce the amount of runoff that needs to be treated, saving space in downstream BMPs.

- Practice Slope – May be used on any slope.
- Depth – The depth of soil amendments can range from 0” where native soils will be retained to 8” for amending soils in place. The depth is dependent on the type of amendment to be used.
- Aesthetics – Soil amendments are underground and are rarely seen. Surface effects of soil amendments may include healthier vegetation and better turf grass establishment.

Landscaping

- It is REQUIRED that the amended soil be established with dense and healthy vegetation as soon as possible after the soil is amended.
- It is HIGHLY RECOMMENDED that vegetation on amended soils be regularly maintained and bare areas seeded. Mowing can be used to maintain vegetation.

Safety

OSHA health and safety guidelines should be followed for safe construction practices. Additional information on safety for construction sites is available from OSHA. Use the following link to research safety measures for construction sites: http://www.osha.gov/pls/oshaweb/

Construction Details

No construction details for soil amendments are provided.

C. Construction Specifications

Amending soils incorporates techniques or steps which may be considered non-standard; it is RECOMMENDED that an engineer experienced in soil amendments be contracted for the final design plans and specifications.

I. Temporary Erosion Control
- ► Installation prior to site disturbance
- ► Catch basin/inlet protection
- ► Secure media with erosion control mat

II. Excavation, Backfill and Grading
- ► Timing of soil amendment
- ► Use of tractor or other equipment to till and amend soils
- ► Stockpiling location (if applicable)
- ► Restoration in the event of disturbance during construction

III. Native Plants, Planting and Transplanting
- ► Site preparation of planting areas
- ► Timing of seeding and planting
- ► Watering of plant material
- ► Weed control

IV. Construction Sequence Scheduling
- ► Varies based on design option (see design procedure)

V. Construction Observation
- ► Adherence to construction documents
- ► Continual site management
- ► Verification of physical site conditions
- ► Erosion control measures installed appropriately
- ► Completion of Construction

D. Operation and Maintenance

Amended soils can be treated the same as non-amended soils. Protecting amended soils from post-construction compaction will increase the soil's stormwater and horticultural benefits. Planting and maintaining native vegetation with deep roots will help maintain the organic composition of the soil and increase infiltration of stormwater.

Construction and Maintenance Costs

No construction and maintenance cost information has been developed to date.

E. Design Procedure

The five variants of soil amendments must be designed individually. The following steps guide the reader through the process needed to address soil amendments on the entire site. The construction sequence of each variant and the method of estimating the quantities of amendment follows.

These options can be used individually, or in combination (more than one may be used in different areas of a single site), so that they work best for the situation. The most convenient and economical methods for achieving the standards depends on site soil conditions, grading and subgrade compaction, practicality of stockpiling site topsoil during grading, and site access issues.

Choose Variant B, C, D and/or E to restore soil quality after construction in areas where grading and soil disturbance are unavoidable, and follow these requirements:

- ► Final soil depth should be a minimum of 8 inches.
- ► Avoid plowing or tilling within drip line of trees.
- ► Test soil pH, and if necessary, adjust to suit proposed plants.

Step 1. Review site conditions, landscape and grading plans

Examine site plans and soils. Use a shovel to dig in several areas that will be graded (or already have been) to determine if the newly exposed grades can be easily amended, or if compaction will require plowing/tilling of the subsoil or topsoil import. Determine if there are areas where soil could be stockpiled on-site.

Step 2. Select soil treatment variant and suitable pH for each planting area.

Amending with compost is often the most economical way to bring poor soils up to the required soil organic matter content. On sites with the original, undisturbed, native soil, and where space permits, stockpiling and reapplying topsoil may be less costly. Importing topsoil usually costs more than amending existing soil, though it may be easier where subsoil conditions make cultivation difficult.

Identify areas where soil can be: left undisturbed (Variant A), amended in place with compost (Variant B), removed and replaced with purchased topsoil (Variant C), or stockpiled and later reapplied (Variant D or E). Clearly outline those areas on the site plan and assign each area an identifying letter (A, B, C, D, or E) on the site drawing.

A) Undisturbed Native Soil – This variant is the most economical and best for the environment but not always feasible.

- ► Plan site development to leave areas where native vegetation does not need to be disturbed.
- ► Fence off areas of native vegetation on the site that will not be stripped, logged, or graded to protect them from disturbance during construction.
- ► Undisturbed areas do not require soil amendment.

B) Amend existing soils in-place – Where the soil has been compacted or the forest duff or topsoil removed, the simplest way to restore soil quality is to rototill compost into the existing soil.

- ► Apply a layer of compost to existing soil at the **amendment depth of 2.5 inches**. Use the worksheet in this chapter to calculate the amount of compost needed. *Retain copies of receipts for compost delivered to the site, as they will be used during inspection to verify the soil requirements have been met.*
- ► Rototill compost into soil to a depth of at least 8 inches. *Note that tilling to this depth will require repeated passes with a large machine, such as a tractor mounted or heavy rear tine rototiller.*

C) Import topsoil mix– Where subsoil is too rocky, compacted or poorly drained to amend effectively; a topsoil mix with 8 – 13% soil organic matter can be imported and placed on the surface.

- Import and apply a topsoil mix with 8 – 13% soil organic matter, which should contain 30 – 40% compost by volume, and clean sand or sandy soil. The soil depth should be 8 inches and the pH suitable for proposed plants. Ask topsoil suppliers for test results of their product to verify the material contains the desired organic matter content and pH. *Retain test result reports and receipts for material delivered to the site, as they will be used during inspection to verify that the soil requirements have been met.*
- For best results, plow or till compacted subsoil at least 2 inches deep before applying topsoil mix, and/or rototill some of the newly applied topsoil into the subsoil.

D) Native Soil: Stockpile site duff and topsoil; reapply after grading and construction – This design variant is only applicable to sites that have the original, undisturbed soil native to the site. This will most often be forested land that is being converted in the current project.

- Remove forest duff layer and topsoil and stockpile *separately, in an approved location prior to grading. Cover soil and duff piles with woven weed barrier (available from nursery supply stores) that sheds moisture yet allows air flow.*
- Reapply topsoil to landscape areas to a minimum 8 inch depth after grading and other disturbances are completed.
- For best results, plow or till compacted subsoil at least 2 inches deep before replacing stockpiled topsoil, and/or rototill some of the replaced topsoil into the subsoil.
- Apply a 2-inch layer of stockpiled duff as a mulch after planting.

E) Disturbed Soil: Stockpile topsoil, reapply and amend in place– This design variant is only applicable to sites where the soil is not the original, undisturbed soil native to the site. This will most often be unforested areas.

- Remove soil and stockpile in an approved location prior to grading. Cover soil with woven weed barrier (available from nursery supply stores) that sheds moisture yet allows air flow.
- Reapply stockpiled soil to landscape areas to a minimum 6 inch depth after grading and other disturbances are completed. In some cases, purchasing additional topsoil will be needed to achieve the 6 inch depth.
- Plow or till compacted subsoil at least 2 inches deep before replacing stockpiled soil, and/or rototill some of the replaced soil into the subsoil.
- Apply a layer of compost to the reapplied soil at a depth of 2.5 inches. Use the worksheet in this booklet to calculate the amount of compost needed. *Retain receipts for compost delivered to the site, as they will be used during inspection to verify the soil requirements have been met.*
- Rototill compost into soil to a depth of at least 8 inches. *Note that tilling to this depth will require repeated passes with a large machine, such as a tractor or heavy rear tine rototiller.*

Step 3. Calculate compost and/or topsoil volumes for each area.

- Calculate the square footage of each lettered area on site plan.
- Use the square footage figures to complete the Compost and Topsoil Calculation in Table 8.46. This will give you the amounts of topsoil and/or compost for 2.5 inch amendment depth in cubic yards needed to achieve the 8 inch soil depth.
- If there is less stockpiled site topsoil than the amount needed to achieve the 8 inch depth once reapplied, additional topsoil should be purchased to make up the difference. Subtract the cubic yards of site topsoil available to be stockpiled from the total amount needed to find the difference—the amount of additional topsoil that will need to be purchased.

Table 8.46. Compost and Topsoil Calculation

	A	B	C	D	E	F	G	H	I	
	Area 1 [SF]	Area 2 [SF]	Area 3 [SF]	Area 4 [SF]	Area 5 [SF]	Total Area (A+B+C+D+E) [SF]	Compost Multiplication Factor	Topsoil Multiplication Factor	Total Compost (F x G) [CY]	Total Topsoil (F x H) [CY]
Variant A							-	-		
Variant B							0.008	-		
Variant C							-	0.025		
Variant D							-	0.025		
Variant E							0.008	0.019		
								Totals [CY]		

Step 4. Identify compost and/or topsoils to be applied and retain records.

- Contact compost or topsoil sources and select products that meet the requirements, including 8 – 13% soil organic matter content for topsoil mixes and suitable pH for the proposed plants.
- Retain compost and/or topsoil product delivery tickets and test reports, as they will be used as verification records during inspection.

F. References

County Board of Supervisors of the County of Dane. 2005. Chapter 14 of the Dane County Code of Ordinances Regarding Erosion Control and Stormwater Management. Dane County, WI.

King County Department of Development and Environmental Services. 2005. Achieving the Post-Construction Soil Standard. King County, Washington.

CHEMICAL AND BIOLOGICAL TREATMENT

Tanners Lake alum injection facility - Oakdale, MN

Definition:
Chemical and biological treatment of stormwater enhances settling of suspended sediment by encouraging flocculation. Variations include aluminum sulfate, ferric chloride, chitosan, and polyacrylamide. Chemical and biological treatments are typically used as a final or polishing step in the treatment train.

KEY CONSIDERATIONS

Design Criteria:

- Properties of water to be treated (pH, sediment concentration, etc.)
- Level of treatment desired
- Requirements for discharge of treated water to receiving water bodies
- Type of facility required or present
- Pre-treatment or secondary treatment requirements
- Maintenance and monitoring requirements of the system

Benefits:

- Quickly removes suspended clays and silts
- Can be used as pre-treatment to remove suspended sediments prior to infiltration
- Can help project meet stringent water clarity and sediment-bound pollutant removal standards
- Suitable for cold climates

Limitations:

- Ongoing operation and maintenance of the chemical addition system may be required
- Monitoring may be required to determine the impact on downstream resources
- A pond or sediment collection area is necessary downstream of the treatment site for settling out the flocculants
- May require permit from DNR
- Expensive to build and operate

MANAGEMENT SUITABILITY

	Volume Control
	Peak discharge/Rate Control
X	Water Quality/Pretreatment
	Wetland Bounce

MECHANISMS

	Infiltration
	Screening/ Filtration
	Temperature Control
X	Settling
	Evaporation
	Transpiration
X	Soil Adsorption
X	Biological/ Micro. Uptake

POLLUTION REMOVAL

X*	Total Suspended Solids
X*	Nutrients - Total Phosphorus/ Total Nitrogen
X*	Metals - Cadmium, Copper, Lead, and Zinc
	Pathogens - Bacteria
	Toxins - Hydrocarbon

* target pollutants - actual percentage of pollutant removal varies with each device and installation

Description:
Chemical and biological agents such as aluminum sulfate, polyacrylamide, ferric chloride, and chitosan can be added to stormwater to encourage the settling of smaller suspended particles. In a typical detention pond, suspended clays and other small particles are not well removed because they require long detention times to settle out. The addition of chemical or biological agents allows the small suspended particles to group together to form a larger conglomerate particle (or flocculent) that rapidly settles out of the water column.

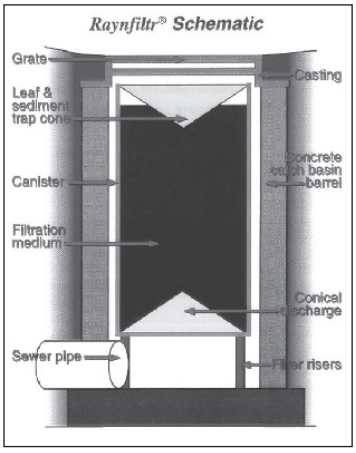
Chemical and biological treatment can be a passive system of flow through a solid form of the media, but it often requires the installation of monitoring and metering devices to ensure that the liquid agent is added at the proper dosage. Chemical or biological treatment can also be used as a temporary or one-time use product for construction or emergency situations.

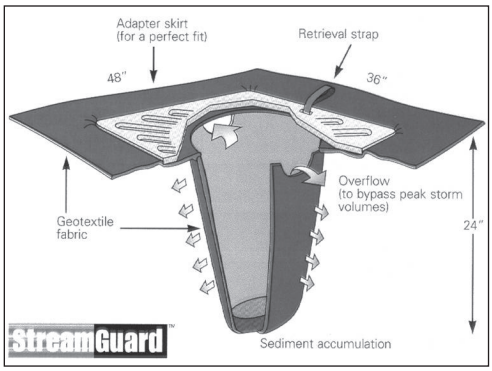
The City of Inver Grove Heights allows limited use of proprietary devices or “alternative methods”. Use of the alternative method must be approved by City staff prior to installation. Approval is limited to those methods that achieve approximately 85% removal of total suspended solids. Additionally, the City requires a two-year monitoring plan to measure the actual effectiveness of the method.

Selection:
When selecting or specifying a device that utilizes chemical or biological treatment processes, designers should research the following:

1. What are the minimum or maximum drainage areas recommended for the device or method?
2. What are the characteristics of the pollutants in the water used for testing? Review manufacturer’s protocols for testing.
3. Are the pollutant removal tests verified by independent organizations such as USEPA, University of New Hampshire, University of Minnesota, Wisconsin Department of Natural Resources, or others?
4. Can the chemical or biological treatment agent be discharged into a natural water body?
5. What detention time is required for the chemical or biological treatment agent to cause flocculation?
6. How often must dosing rates be changed?
7. What are the construction costs? Does the cost include all materials, installation, and delivery?
8. What are the maintenance requirements? What are the costs of the required maintenance? Is there a standard operation and maintenance plan?
9. Will the manufacturer provide design computations and CADD details?

FILTRATION DEVICES





Proprietary systems used as an example only - NOT an endorsement

Definition:
Filtration devices (inserts) allow stormwater to pass through filter media which are designed to reduce specific stormwater pollutants, but primarily solids and oils. Pollutants are captured physically or through sorption onto the filter media. Filters may either be inserts that are retrofitted into existing catch basins or manholes, or stand alone units supplied by a manufacturer.

KEY CONSIDERATIONS

Design Criteria:
- Pollutants of interest for reduction
- Desired removal efficiency
- Design flow or volume, site constraints on size, desired location of treatment unit
- Pre-treatment requirements
- Installation and maintenance costs, life of unit

Benefits:
- Units are typically underground or within existing structures and do not consume much site space
- Filtration devices can be customized to reduce a specific pollutant of concern
- Can often be easily incorporated into fully developed sites
- Can be used for pre-treatment prior to infiltration practices
- Relevant for use on industrial sites because filters can remove pollutants such as metals and oils

Limitations:
- Efficiency has not been widely tested
- Each type of unit has specific design constraints and limitations for use
- Can be more costly that other treatment methods
- Treatment may be greatly reduced if frequent maintenance is not conducted
- Subject to freezing in cold climates

MANAGEMENT SUITABILITY

	Volume Control
	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
	Wetland Bounce

MECHANISMS

	Infiltration
X	Screening/ Filtration
	Temperature Control
	Settling
	Evaporation
	Transpiration
	Soil Adsorption
	Biological/ Micro. Uptake

POLLUTION REMOVAL

X*	Total Suspended Solids
	Nutrients - Total Phosphorus/ Total Nitrogen
X*	Metals - Cadmium, Copper, Lead, and Zinc
	Pathogens - Coliform, Streptococci, E. Coli
	Toxins - Chloride, Hydrocarbon, Pesticide

* target pollutants - actual percentage of pollutant removal varies with each device and installation

Description:
Filtration devices, depending on the design, can treat stormwater to reduce nutrients, sediment, floatables, metals, oil, and/or organic compounds. Different filtration media are used depending on the type of pollutant to be removed. Filter media may be a screen, fabric, activated carbon, perlite, zeolite, or other materials. Often a combination of filter media can be used to target the specific pollutants of interest.

These devices differ from the structural stormwater filters described earlier in Chapter 8 in two aspects. First, these devices are proprietary and are designed to fit as an insert into the hydraulic infrastructure (eg. a catch basin). Second, the media material may have unique characteristics which are different from the soil/sand media recommended for general stormwater filtration.

Filtration devices have been developed for use in locations such as underground chambers, catch basins, trench drains, and roof drains. The manufacturer specifications should indicate key design parameters such as size, allowable flow rate, allowable pollutant concentrations, and removal efficiency. A bypass should be part of the system to allow high flows to circumvent the filtration device.

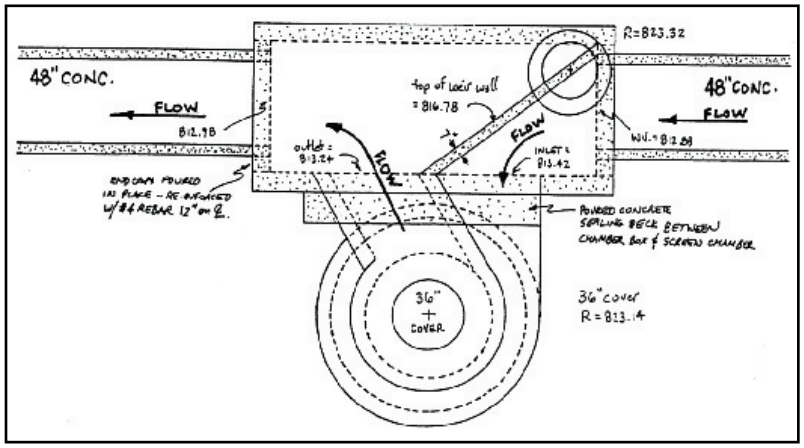
Performance data are often provided by the manufacturer. Users should review this information to ensure it was provided by an independent source.

The City of Inver Grove Heights allows limited use of proprietary devices or “alternative methods.” Use of the alternative device as a stand alone BMP must be approved by City staff prior to installation. Approval is limited to those devices that achieve approximately 85% removal of total suspended solids. Additionally, the City requires a two-year monitoring plan to measure the actual effectiveness of the method. If a device does not meet this 80% total suspended solids removal requirement, then these devices could be used as pretreatment or supplemental to another stormwater practice.

Selection:
When selecting or specifying a filtration device, designers should research the following:

1. What are the minimum or maximum drainage areas recommended for the device or method?
2. What flow rates or volumes can the device accommodate? Will accessory structures be necessary to divert high flow around the filtration device?
3. What are the characteristics of the pollutants in the water used for testing? What particle size distribution was tested? Research protocols used for testing.
4. Are pollutant removal tests verified by independent organizations such as USEPA, University of New Hampshire, University of Minnesota, Wisconsin Department of Natural Resources, or others?
5. Does the device contain a by-pass for high flows? If so, then what is the percentage of flow is prior to by-pass.
6. What are the construction costs? Does the cost include all materials, installation, and delivery?
7. What are the maintenance requirements? What are the costs of the required maintenance? Is there a standard operation and maintenance plan? What is the typical life of the filtration unit?
8. Does the local regulatory authority approve the use of filtration devices?
9. Will the manufacturer provide design computations and CADD details?

HYDRODYNAMIC DEVICES



Courtesy of Minneapolis Public Works Department

Definition:
Hydrodynamic devices are designed to remove solids, oil/grease, floatables and other debris from stormwater runoff through gravitational trapping of pollutants. Typically used in combination with other structural BMPs, such as a pre-treatment device.

KEY CONSIDERATIONS

Design Criteria:

- Expected flow rates
- Pollutants of concern
- Desired removal efficiencies
- Site constraints for size
- Installation and maintenance costs, life of unit
- Need for accessory structures

Benefits:

- Units are typically underground and do not consume much site space
- Can often be easily incorporated into fully developed sites
- Can be used for pre-treatment prior to other practices
- Suitable for cold climates if installed below frost line

Limitations:

- Each type of unit has specific design constraints and limitations for use
- Treatment may be reduced if frequent maintenance is not conducted
- May not meet local standards when used alone
- Generally good for solids and litter, but much less effective for other common pollutants.

MANAGEMENT SUITABILITY

	Volume Control
	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
	Wetland Bounce

MECHANISMS

	Infiltration
X	Screening/ Filtration
	Temperature Control
X	Settling
	Evaporation
	Transpiration
	Soil Adsorption
	Biological/ Micro. Uptake

POLLUTION REMOVAL

X*	Total Suspended Solids
	Nutrients - Total Phosphorus/ Total Nitrogen
X*	Metals - Cadmium, Copper, Lead, and Zinc
	Pathogens - Coliform, Streptococci, E. Coli
	Toxins - Chloride, Hydrocarbon, Pesticide

* target pollutants - actual percentage of pollutant removal varies with each device and installation

Description:
Hydrodynamic devices are chambers that allow sediment to settle out of the water column. The devices often enhance the rate of sediment settling through the circular motion of stormwater within the chamber. The devices also capture oil, grease, and other floatables, most often through the use of baffles. Hydrodynamic devices are typically designed to provide optimal removal efficiency for smaller, more frequent storms with minimal removal in larger, less common storms. To maintain removal efficiency, the devices require regular removal of accumulated sediment and floatables.

These devices are proprietary and typically are designed and installed by a manufacturer. Performance data are often provided by the manufacturer. Users should review this information to ensure it was provided by an independent source.

The City of Inver Grove Heights allows limited use of proprietary devices or "alternative methods." Use of the alternative device as a stand alone BMP must be approved by City staff prior to installation. Approval is limited to those devices that achieve approximately 85% removal of total suspended solids. Additionally, the City requires a two-year monitoring plan to measure the actual effectiveness of the method. If a hydrodynamic device does not meet this 80% total suspended solids removal requirement, then the device could be used as pretreatment or supplemental to another stormwater practice. No single, stand alone device has been found to meet this criteria.

Selection:
When selecting or specifying a hydrodynamic device, designers should research the following:

1. What are the minimum or maximum drainage areas recommended for the device or method?
2. What flow rates or volumes can the device accommodate? Will accessory structures be necessary to divert high flow around the hydrodynamic device?
3. What are the characteristics of the pollutants in the water used for testing? Research protocols used for testing.
4. Are pollutant removal tests verified by independent organizations such as USEPA, University of New Hampshire, University of Minnesota, Wisconsin Department of Natural Resources, or others?
5. Does the device contain a bypass for high flows? If so, then what percentage of flow is treated prior to bypass?
6. What are the construction costs? Does the cost include all materials, installation, and delivery?
7. What are the maintenance requirements? What are the costs of the required maintenance? Is there a standard operation and maintenance plan?
8. Does the local regulatory authority allow the use of hydrodynamic devices?
9. Will the manufacturer provide design computations and CADD details?