DuPage County

Water Quality Best Management Practices Technical Guidance

For Inclusion into Appendix E – Technical Guidance for the DuPage Countywide Stormwater and Flood Plain Ordinance

March 2008

Prepared by:
DuPage County Stormwater Management Committee

With
DuPage County
Economic Development and Planning
And
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This manual was created for the DuPage County Stormwater Management Committee under the direction of Chairman James Zay.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge participation and contributions of the Municipal Engineers Technical Advisory Committee and the Water Quality Stakeholders Committee for the development of the DuPage County Water Quality Best Management Practices Technical Guidance for inclusion in Appendix E. These committees acted as advisory groups during the two-year development process concluding with the approval of the manual by the County Board on April 8, 2008.

A special thanks goes out to all that provided assistance and suggestions via written advice, meetings and phone conversations during the development phase. Those who made contributions that are especially notable include:

Airhart Construction
A.McGurr, LTD., P.C.
Contech Stormwater Solutions, Inc.
EnCap, Inc.
Imbrium Systems, Inc.
Planning Resources, Inc.
StormTech, LLC.
V_3 Companies
Village of Oakbrook

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Section 1

INTRODUCTION

1.1 Purpose and Background

This manual is an addition to the DuPage County Technical Guidance Document, Appendix E of the DuPage County Stormwater Management Plan (June 1989).

The manual is not regulatory in scope. However, the planning and selection guidelines found in this manual are intended to help demonstrate compliance with regulations such as those found in the DuPage County Countywide Stormwater and Flood Plain Ordinance (Appendix F of the DuPage County Stormwater Management Plan); the National Pollutant Discharge Elimination System (NPDES); and the Clean Water Act (CWA), Section 401 & 404.

The purpose of this manual is to provide guidance on the design and implementation of measures to prevent stormwater quality degradation and to enhance overall stormwater quality. These measures manage stormwater quality through the control, capture and treatment of stormwater pollutants. Such measures are generally referred to as Best Management Practices (BMPs). This BMP manual is primarily intended to provide guidance on the selection of permanent BMPs for new construction. Permanent BMPs are those practices that address the water quality issues associated with the long term use of a property. The manual does not address BMPs such as construction site erosion and sediment control practices or other temporary or more transient practices and landscape features such as rain barrels and water gardens.
Many permanent BMPs can also be implemented on existing land-uses to improve stormwater quality. Therefore, the guidance found herein is intended to present effective and economical BMPs for both new construction and existing land uses that are appropriate for the physical geographic and climatic characteristics of DuPage County, Illinois.

Those who may benefit from the use of this manual include land planners, engineers, inspectors, subcontractors, and property owners.

The manual is divided into four general sections. Following this introductory section, which includes a brief overview of water quality problems in urban areas and the regulatory environment, the manual introduces the BMP concept including issues such as watershed considerations, geography/geology, BMP selection process, and the BMP treatment train. Next is a section providing design details, performance comparisons, costs, and commentary on specific BMPs. Here, specific BMPs are grouped by use (e.g. conveyance, detention, etc.) to assist the reader in the BMP selection process. The last section provides useful information via appendices and a glossary.

1.2 Stormwater Pollutants

Stormwater pollutants enter receiving waters from “point” and “non-point” sources. Point sources refer to pollutants originating from sources such as regulated discharges, and accidental or illegal dumping. Non-point sources originate from stormwater runoff that picks up and transports natural and man-made substances into receiving waters. Common pollutants found in DuPage County and their associated impacts are shown in Table 1-1.

Table 1-1
Common Pollutants in Urban Runoff and Associated Impacts

Pollutant	Sources	Impacts
Solids (suspended sediment, floatables, dissolved chloride, sulfates)	Litter, road runoff, soil erosion from construction, streambanks, croplands and untreated sites, cleared vegetation, human & animal waste, vehicle fuels & fluids, vehicle wear, industrial/household chemicals, industrial processes, pool waters discharged improperly, road salt used for de-icing, snow runoff	Increased turbidity, reduced light penetration, impaired respiration for aquatic life, impairment of fishing resources, increased sedimentation, toxic to aquatic life, prevents vertical spring mixing
Biochemical Oxygen Demand	Decaying vegetation, excessive growth of vegetation, soil erosion, human & animal waste, vehicle fuels & fluids, vehicle wear, industrial/household chemicals, industrial processes, pesticides	Kills aquatic life
Metals (Cadmium, Chromium, Copper, Iron, Lead, Mercury, Nickel, Silver, Zinc)	Road runoff, tire wear, wear of clutch and brake linings, soil erosion, human & animal waste, vehicle fuels & fluids, vehicle wear, industrial/household chemicals, industrial processes, paints, pesticides	Toxic to aquatic life, potential for ground water contamination, accumulates in fish and shellfish tissues that may be consumed by humans
Pathogens (bacteria, fecal coliform)	Septic tank overflows/leaks/failures, illicit discharge from sanitary sewers into storm sewers, sanitary sewer over flows, untreated or inadequately treated sewage, animal waste	Unsafe conditions for human contact/swimming, closed beaches, contaminated ground and drinking water
Oil (oil, grease, fuels, lubricants)	Industrial spills, runoff from streets, gas stations, & parking lots, improper disposal of used oil into storm drains, business districts, shopping centers, office parks, vehicle fuels & fluids, fuel combustion, industrial/household chemicals, industrial processes, paints	Kills aquatic life, builds up in sediment and remains for a long time
Nutrients (Nitrogen, Phosphorus, Nitrates)	Agriculture, improper composting and yard waste disposal, septic tanks, soil erosion, cleared vegetation, fertilizers, animal waste, fuel combustion, industrial/household chemicals, industrial processes, atmospheric deposition onto impervious surfaces that become runoff	Depressed dissolved oxygen levels, elevated phytoplankton populations, fish kills by hypoxia & anoxia, release of toxins from sediments, decreased fisheries yields, may contaminate ground water, excessive plant growth
Herbicides, Pesticides, Insecticides	Improper or excessive use of lawn chemicals, agriculture	Algae blooms, fish kills

1.3 Impact of Urbanization on Stormwater Runoff

Urban development alters the hydrology of a site which results in direct and indirect impacts to the watershed. Urbanization affects both the quality and quantity of stormwater leaving the development site. Impacts typically occur during construction activities and after the development is completed. As development continues over time, watershed impacts increase in magnitude resulting in flooding and water quality degradation. As population increases, the biotic integrity of rivers and streams rapidly declines. The Illinois EPA has observed that most rivers and streams show marked impairment as populations approach 300 people per square mile (IEPA, 1994).

The increased quantity of stormwater runoff entering receiving waters results in the loss of equilibrium in natural water features and associated negative impacts such as shoreline and stream bank erosion, channel down cutting, and wetland sedimentation. Development within wetlands, floodplains, and riparian areas results in the loss of the stormwater benefits provided by these water resource features further exacerbating negative impacts to the watershed. Eventually a point may be reached where the social and economic costs due to the loss of water resources becomes unacceptable to the populace. The cost to mitigate for lost water resource benefits due to development can be taxing on local and State government.

1.3.1 Impact of Urbanization on Stormwater Runoff in DuPage County

DuPage County is approximately 334 square miles in size and has experienced rapid urbanization over the past several decades, beginning in the 1960's. The population of the County roughly tripled from a 1960 population of 300,000 to about 900,000 in 1990. The population estimate as of the 2004 census is 928,718 (about 2,780 people per square mile). While population growth has slowed in recent years, development continues in most communities as obsolete housing is replaced in response to changing land use.

The original prairie, woodland, and wetland landscape features in DuPage County were modified to augment agricultural uses through the clearing of land, draining of wetlands, and the channelization and creation of waterways. With the advent of urbanization, increasing areas of urban development were hydraulically connected to the agricultural drainage system. Over time, this has resulted in increased flooding and water quality degradation. The IEPA Bureau of Water currently assesses the majority of DuPage County rivers and streams as "fair" in overall resource quality. Approximately 2/3 of the State's rivers and streams are considered "good" and about 1/3 of the States rivers and streams fall into the "fair" category. Less than 2% are categorized as "poor". The State's 2004 Total Maximum Daily Load (TMDL) assessment (Table 1-2) addressed the following water quality impairments in DuPage County rivers and streams:

Table 1-2
DuPage County Water Quality Impairments

Water Body Name	Length Miles/ Acres	2004 303(d) Impairments	Impairments addressed in TMDL	Status
East. Branch DuPage	13.15	Cyanide, siltation, flow regime alteration, nitrates, Dissolved Oxygen (DO), Total Dissolved Solids (TDS), habitat alteration, Total Suspended Solids (TSS), phosphorus	DO, TDS, TSS, algae, phosphorus	Approved October 2004
West Branch DuPage	17.8	nitrogen, pH, siltation, DO, chlorides, flow regime alteration, habitat alteration, flow alteration, pathogen, TSS, TDS, phosphorus	TDS, copper	Approved October 2004
Salt Creek	29.01	nitrogen, siltation, DO, TDS, habitat alteration, flow regime alteration, aldrin, algae, aquatic plants (native), TSS, DDT, chlorides, heptachlor, PCB, mercury, zinc, nickel, phosphorus, pathogens	DO, TDS,	Approved October 2004
Addison Cr.	11.37	nitrogen, copper, nitrates, TDS, TSS, chlorides, flow regime alteration, habitat alteration, pathogens, aldrin, DDT, hexachlorobenzene, total chromium, nickel, phosphorus, algae	DO, chlorides, copper, TDS	
Spring Brook	3.28	priority organics, nitrates, siltation, DO, flow regime alteration, habitat alteration, TSS, algae, phosphorus	DO	
Meacham Cr.	2.88		DO	
Busse Woods Reservoir	590	priority organics, TDS, algae, PCB	phosphorus	

Source: Condensed from Illinois Environmental Protection Agency DuPage County 2004 TMDL Status Report

1.4 Relevant Water Resource Regulations

The following is a summary of the relevant Federal, State and local water resource regulations that may apply in the implementation of BMPs in DuPage County. It is not the intention of this manual to provide an exhaustive listing of all applicable water resource regulations. For the reader's convenience, regulatory agency contact information and sources of additional information are provided after each category.

National Pollutant Discharge Elimination System (NPDES)

The National Pollutant Discharge Elimination System (NPDES) Program is a regulatory function of the 1972 Clean Water Act created to regulate pollutant discharges into receiving waters. Stormwater pollutants are addressed through the implementation of two phases of the program. Both phases require permits for certain activities deemed likely to have a high potential for negatively impacting water quality. Those phases are as follows:

<u>NPDES Phase I Regulated Discharges</u>

- Municipal Separate Storm Sewer Systems (MS4s) located in incorporated places or counties with populations of 100,000 or more; and
- Eleven categories of industrial activity, one of which is construction activity that disturbs five or more acres of land.

Industrial activities under Phase I involve businesses engaged in paper production, land fill operation, mining, chemical production and other activities with a high potential of negatively impacting water resources. The Storm Water Pollution Prevention Plans (SWPPP) for such activities are industry specific and are not a subject of this manual. Also, MS4 communities must obtain an NPDES Phase I permit. Many of the BMPs found in this manual are appropriate measures to take to help bring about and maintain compliance with the NPDES permit requirements. Phase I also covers construction activity equal or greater than 5 acres in size. A SWPPP is required and a NPDES permit must be obtained in order to undertake such activity. For earth disturbance construction activities, the focus of the SWPPP is erosion and sediment control. Detailed erosion and sediment control plans are also required under the permit requirements of the DuPage County Countywide Stormwater and Flood Plain Ordinance (DCSFPO).

<u>NPDES Phase II Regulated Discharges</u>

- Construction activities disturbing less than five acres but more than or equal to one acre;
- Industrial activities not exposed to stormwater;
- Municipal Separate Storm Sewer Systems (MS4s) located in urbanized areas not covered under Phase I;
- Municipally owned industrial facilities that were addressed under Phase I but granted an extension under the Intermodal Surface Transportation Efficiency Act (ISTEA).

Phase II expanded the number of communities deemed as MS4 and covered additional industrial activities. Of particular importance to development issues, is the new standard of regulating construction activities less than 5 acres and more than or equal to 1 acre. This Phase II category covers most small construction sites including many single family residential sites. In these cases a SWPPP must be developed but instead of submitting the SWPPP and obtaining a permit for the activity, the responsible party can submit a

Notice of Intent (NOI). Among other information, the NOI identifies responsible parties and obligates them to undertake certain actions such as implementing the SWPPP. As with Phase I construction activities, the focus of the SWPPP is erosion and sediment control. Detailed erosion and sediment control plans are required under the DCSFPO. One final note concerning Phase II construction sites less than 1 acre is that they can be regulated under NPDES if the activity would adversely affect water quality. Construction sites less than 1 acre located adjacent to waterways, lakes, ponds, and wetlands are likely regulated under Phase II.

In Illinois, the NPDES Program is administered through the Illinois Environmental Protection agency.

Additional information on State of Illinois water quality regulatory requirements can be obtained from the Illinois EPA web site: http://www.epa.state.il.us/regulations.html.

Additional information on the Federal Clean Water Act may be obtained at the Federal EPA website:
http://www.epa.gov/epahome/rules.html.

Clean Water Act Section 404 Regulated Activities

Section 404 of the Clean Water Act (CWA) empowers the Federal Government with the authority to regulate discharges of dredged or fill material in waters of the United States, including wetlands. Mechanized land clearing, grading, leveling, ditching, and redistribution of material within "waters of the United States", including wetlands, are examples of regulated activities. "Waters of the United States" is broadly defined and includes the navigable waters of the United States and most other lakes, rivers, streams, wetlands, bogs, sloughs, wet meadows, ponds, etc. Permits are required for most activities. Permits are issued by the U.S. Army Corps of Engineers (Corps)

In 1995, the Corps issued General Programmatic Permit No. 25 (GP 25) to DuPage County. GP 25 recognized the DCSFPO as being at least as stringent as the applicable CWA Section 404 regulatory requirements. This allows for an expedited Federal CWA permit issuance process.

Additional information on the DCSFPO may be obtained at:
http://www.dupageco.org/stormwater/

Additional information on the CWA Section 404 and General Programmatic Permit 25 may be obtained at:
http://www.lrc.usace.army.mil/co-r/index.htm.

Clean Water Act Section 401 Regulated Activities

The Illinois Environmental Protection Agency (IEPA) provides water quality certification pursuant to Section 401 of the CWA for all projects requiring a Corps Section 404 permit. This certification is initiated through the Section 404 permit application process. However, the IEPA permitting authority for pollutant discharge activities extend beyond that of the CWA Section 401 water quality certification.

For further information on CWA Section 401 water quality certification and additional IEPA regulations see: http://www.epa.state.il.us/regulations.html

Illinois Department of Natural Resources (IDNR), Office of Water Resources (OWR), Floodway Construction Rules

Under 17 Illinois Administrative Code, Part 3708 (3708 rules), the State of Illinois regulates certain activities in floodways. Regulatory floodways may be those defined by the Federal Emergency Management

Agency (FEMA) National Flood Insurance Program (NFIP) Floodway Map, or as otherwise defined by IDNR/OWR.

In 1998, The State delegated the review and issuance of most State regulated floodway activity to DuPage County through the County's implementation and enforcement of the DCSFPO.

For further information on the 3708 Rules and other OWR regulatory programs: http://dnr.state.il.us/owr/resman/permitprogs.htm.

DuPage County Countywide Stormwater and Flood Plain Ordinance (DCSFPO)

The DCSFPO is identified as Appendix F of the DuPage County Stormwater Management Plan. The DCSFPO is enforced countywide through cooperation with County municipalities. The DCSFPO is the primary regulation affecting new development within the County. It regulates all activities that affect the discharge of stormwater. The DCSFPO includes permit requirements for stormwater runoff, stormwater detention, wetlands, floodplain, floodway, riparian, and water quality BMPs.

The DCSFPO is typically updated on an annual basis. It is important to refer to the current ordinance. The current DCSFPO language may be found at: http://www.dupageco.org/stormwater/

Municipal Water Resource Regulations

Besides taking an active role in the implementation and enforcement of the DCSFPO, DuPage municipalities reserve the right to implement and enforce stricter regulations than those found in the DCSFPO or may adopt additional water resource regulations.

Additional information on municipal requirements may be obtained through municipal web pages.

(End of Section 1)

Section 2

GENERAL OVERVIEW OF BEST MANAGEMENT PRACTICES (BMPs)

2.1 Introduction

Stormwater BMPs are measures that manage stormwater quality through the control, capture and treatment of stormwater pollutants. The concept of the BMP can be better understood by placing BMPs into identifiable categories based on existing or proposed land uses or treatment goals. In DuPage County, these categories are:

1. <u>Stormwater Treatment BMPs-</u> This category addresses stormwater quantity and quality. Typical BMP examples are constructed wetland detention basins, infiltration swales and vegetated buffers. Such BMPs may be utilized for retro-fitting existing land-uses or for proposed land-uses. Stormwater treatment BMPs are usually permanent in nature.

2. <u>Sediment and Erosion Control BMPs-</u> This category includes most construction sites, and eroding pond shorelines and stream banks. These BMPs are intended to prevent the suspension of sediment in receiving water bodies. Common BMPs include permanent and temporary practices such as silt fencing, sedimentation traps, and bank stabilization measures.

3. <u>Pollution Prevention BMPs-</u> This category is activity based and is often termed "good housekeeping activities". These BMPs are designed to prevent or minimize stormwater pollution from common public or private activities by following a pollution prevention plan or procedure. BMPs meeting this classification activity such as municipal street sweeping, commercial grease traps, roadway salt alternatives and spill prevention plans and/or structures.

With regard to the selection of BMPs, DuPage County strongly encourages the following two principles:

1) **Utilization of efficient and cost effective BMPs.**
   This means considering BMPs with the following characteristics:
   - Simple to design and construct;
   - Easy to maintain;
   - Proven long-term effectiveness;
   - Cost effective solution.

   By considering the above in the BMP selection process, short-term and long-term avoidance of the discharge of stormwater pollutants may be realized.

2) **Avoid and minimize impacts as the foremost BMP.**
   Site development and activity planning that considers the minimization and avoidance of impacts to water quality can result in greater cost effectiveness and long-term success of the water quality pollution control plan. Avoiding and minimizing the impacts of construction and as part of long term land planning often results in a lesser quantity of stormwater runoff requiring treatment and less degraded pre-treatment stormwater runoff. As a result, it may be possible to select BMP designs that are less costly or smaller in size,

leading to the realization of significant cost savings.

2.2 BMP Selection Process

As previously noted in the introduction of Section 2, placing BMPs into broad use categories helps to determine their effective application. Next we must consider how to select BMPs that are appropriate for specific types of proposed developments, land practices, and land use activities common to an urban area such as DuPage County. As previously noted in Table 1-1, there are many differing types of potential stormwater pollutants found in urban environments. Land-use is an important factor in determining potential stormwater pollutants. For instance, commercial/industrial land uses will likely generate larger quantities of oil/grease and trace metals than a low-density residential development. Table 2-1 provides a general ranking of expected pollutant load based on land use.

Table 2-1
Land-use Pollutant Load in Descending Order

	Land Use
●	Industrial and waste management sources. Multi-family housing, commercial uses such as gas stations and shopping centers, highways, single family housing with <1/3 acres lots
◕	Single-family housing developments with >1/3 acre lot size, and secondary roads.
◑	Parks, playing fields, and other recreational uses utilizing manicured landscapes.
◔	Undeveloped, unfertilized vegetation

However, other issues such as the proximity and density of the development or activity to major waterways or high quality aquatic resources are also important factors in the BMP selection process. The potential for environmental damage is much greater when a development is hydraulically connected to a water resource, or is in such close proximity that large storm events or accidental releases of pollutants can discharge overland into the resource.

Other factors that influence the BMP selection process include cost effectiveness, government regulations, public concerns and perceptions, and feasibility. Just as each development is unique, the wide range of influencing factors will cause the number and scope of BMPs to vary from project to project. Therefore, it is important to remember that **BMPs must be tailored to each individual site development or activity.**

The first step in the BMP selection process is to identify treatment goals. Simply stated, the ultimate goal of the utilization of BMPs is to discharge clear stormwater that is free from natural or man-made pollutants. While this may not be obtainable in every case, for a variety of environmental and anthropogenic reasons, working towards this goal involves identifying likely pollutants and their sources and then selecting the most effective BMPs. Table 1-1 lists individual pollutants in categories based on land use and typical source to aid in the BMP selection process.

Based on Table 1-1, most land development and many land use activities involve more than one, if not all of the targeted pollutant categories. Therefore, consideration must be given to the **magnitude** of each pollutant category with respect to the development or activity so that correct, efficient, and cost effective BMPs can be selected for each targeted category. Numerous studies have been completed in recent years identifying that one of the more critical pollutants caused by most types of urban development and activity is Total Suspended Solids (TSS). Common TSS constituents in urban areas are sediment, floating debris, and dissolved chlorides and sulfates. Fortunately, BMPs commonly used to reduce TSS, also effectively mitigate stormwater pollutants in other pollutant categories. For instance, heavy metals such as lead, nickel, copper, and zinc are often attached to sediment. This helps simplify the selection process in many cases as selecting BMPs that target TSS will likely be more cost effective and efficient then selecting a BMP for each targeted category. As a result, many types of BMP designs and pre-manufactured products are now available to address TSS.

Typical BMPs suitable for nutrient removal include:

1. Naturally vegetated detention basins;
2. Constructed wetland detention basins;
3. Filter strips;
4. Vegetated swales;
5. Manufactured BMPs;

A summary of BMPs and their ability to address certain stormwater pollutants may be found in Table 2-2.

A second critical pollutant category in DuPage County is nutrient laden runoff (nutrients). The use of fertilizers, animal droppings, and certain industrial processes are the main sources of nutrient laden runoff. In DuPage County, single family residential, golf courses, and commercial developments boasting broad expanses of manicured landscapes are a main source of nutrients in stormwater runoff. These types of land use rely heavily on fertilizers and pesticides and often attract a large number of Canada Geese. Goose droppings contain a high level of nutrients, contributing further to the overall nutrient load in stormwater runoff. This fact, paired with the often aggressive nature of the species, makes discouraging flocks of geese a good practice. Another significant source of nutrients are improperly maintained septic fields. Due to the local scarcity of sanitary sewer, substantial areas of DuPage County are served by individual septic fields. In addition, recent studies have shown that impervious surfaces such as roads and parking lots contribute heavy metals, oils, grease, and hydrocarbons to runoff. This type of land cover has also been found to collect and conduct nutrient laden rainfall that results from nitrogen bearing compounds being present in the atmosphere.

Two components of nutrient laden runoff, nitrogen and phosphorous, are of particular concern in DuPage County. Nitrogen is present in the environment in several different inorganic and organic forms and phosphorus is generally present in the inorganic form of phosphate. These two pollutants are responsible for major problems that are commonly associated with high nutrient loads. Nitrogen and phosphate laden runoff that reaches water bodies can cause serious water quality problems that threaten to degrade the overall ecology and aesthetic quality of our waters. These problems include unwanted stimulation of microorganisms, algal blooms, a reduction in dissolved oxygen levels, and resultant fish kills. Nutrients in stormwater can cause nitrate contamination in groundwater aquifers. Nitrates in drinking water are a health concern. While most of DuPage County's potable water originates from Lake Michigan and/or municipal deep aquifer wells, which are largely immune to nitrate contamination by DuPage County land-use practices, significant residential areas of the County still rely on the shallow aquifer for potable water. This bedrock aquifer is recharged directly by local rainfall through overhead soils. Historically, with proper fertilizer application practices, serious nitrate contamination of the shallow aquifer has not been an issue in DuPage. However, care must be taken when locating certain BMPs near private well heads to avoid accidental contamination through groundwater infiltration.

Typical BMPs suitable for nutrient removal include:

1. Avoiding over-use of fertilizer or the use of fertilizer where stormwater runoff may easily reach drainage ways and waterbodies;
2. Buffer strips of unfertilized vegetation;
3. Infiltration;
4. Detention basins.

A summary of BMPs and their ability to address certain stormwater pollutants may be found in Table 2-2.

The BMP Treatment Train Concept

In considering the above discussion of common stormwater pollutants and their removal through BMPs, it becomes apparent that there can be a certain logical, on-site application of appropriate BMPs that allows for a more efficient and effective pollution control plan. Commonly known as the BMP Treatment Train**,** this concept involves using BMPs sequentially and redundantly to improve efficiency and reduce cost. An example of the treatment train concept could be using BMPs such as minimization of impervious area to reduce pollutant loading and runoff volume requiring treatment coupled with the installation of filter strips upstream in the project to reduce TSS and nutrients in runoff before it reaches larger scale BMPs (such as a wet bottom detention facility). This logical layout of a series of BMPs can ultimately reduce construction costs and increase system reliability by reducing stormwater runoff volume and allowing for more efficient pollutant removal.

BMP Designs in Table 2-2

1. **Filter Strip**: 100 feet wide turf strip.
2. **Filter Strip**: 200 feet wide forested strip with level spreader.
3. **Vegetated Swale**: 100 ft length.
4. **Vegetated Swale**: 200 ft length.
5. **Infiltration Basin**: Facility exfiltrates first-flush; 0.5 inch runoff per impervious acre.
6. **Infiltration Basin**: Facility exfiltrates 1.0 inch runoff volume per impervious acre.
7. **Infiltration Basin**: Facility exfiltrates all runoff, up to the two year design storm.
8. **Infiltration Trench**: Facility exfiltrates first-flush; 0.5 inch runoff per impervious acre.
9. **Infiltration Trench**: Facility exfiltrates 1.0 inch runoff volume per impervious acre.
10. **Infiltration Trench**: Facility exfiltrates all runoff, up to the two year design storm.
11. **Pervious Pavement**: Facility exfiltrates first-flush; 0.5 inch runoff per impervious acre.
12. **Pervious Pavement**: Facility exfiltrates 1.0 inch runoff volume per impervious acre.
13. **Pervious Pavement**: Facility exfiltrates all runoff, up to the two year design storm.
14. **Manufactured Structures**: Media Filters
15. **Manufactured Structures**: Manufactured Structures
16. **Detention Basin**: First-flush runoff volume detained for 6 to 12 hours.
17. **Detention Basin**: Runoff volume produced by 1.0 inch, detained for 24 hours.
18. **Detention Basin**: Runoff volume produced by 1.0 inch, detained for 24 hours in shallow marsh.
19. **Dry Detention Basin:** Without extended detention

20. **Dry Detention Basin:** Extended detention with forebay and micropool
21. **Wet Detention Pond**: Permanent pool equal to 0.5 inch storage per impervious acre.
22. **Wet Detention Pond**: Permanent pool equal to 2.5 (Vr); where (Vr) =mean storm runoff.
23. **Wet Detention Pond**: Permanent pool equal to 4.0 (Vr); approximately 2 weeks retention.
24. **Constructed Wetland Detention:** Shallow Marsh
25. **Constructed Wetland Detention:** Combination Pond/Wetland
26. **Constructed Wetland Detention:** Extended Wetland Detention

Table 2-2 Pollutant Removal Rates of Urban BMP Designs

BMP	Total Suspended Solids	Total Phosphorus	Total Nitrogen	Biochemical Oxygen Demand	Metals	Bacteria	Oil	Nutrients	Pesticides	Overall Removal Capability
Filter Strip										
1	◔	○	○	○	◔	⊗	⊗	⊗	⊗	Low
2	◕	◑	◑	◕	◕	⊗	⊗	⊗	⊗	Moderate
Vegetated Swale										
3	◑	◑	○	◔	○	⊗	◑	⊗	⊗	Low
4	●	◔	◔	◔	◑	⊗	◕	⊗	⊗	Moderate
Infiltration Basin										
5	◕	◑	◑	◕	◑	◕	⊗	⊗	⊗	Moderate
6	●	◑	◑	◕	●	◕	⊗	⊗	⊗	High
7	●	◕	◕	●	●	●	⊗	⊗	⊗	High
Infiltration Trench										
8	◕	◑	◑	◕	◕	◕	⊗	⊗	⊗	Moderate
9	●	◑	◑	◕	●	◕	⊗	⊗	⊗	High
10	●	◕	◕	●	●	●	⊗	⊗	⊗	High
Pervious Pavement										
11	◑	◕	◑	◕	◑	◕	⊗	⊗	⊗	Moderate
12	●	◕	◕	◕	●	●	⊗	⊗	⊗	High
13	●	◕	◕	●	●	●	⊗	⊗	⊗	High
Manufactured Structures										
14	●	◔	⊗	⊗	◔	⊗	⊗	⊗	⊗	High
15	◕	⊗	⊗	⊗	⊗	⊗	●	⊗	⊗	High
Detention Basin										
16	◕	◔	◔	◔	◑	⊗	⊗	⊗	⊗	Moderate
17	●	◑	◔	◑	◕	⊗	⊗	⊗	⊗	Moderate
18	●	◕	◑	◑	◕	⊗	⊗	⊗	⊗	High
Dry Detention Pond										
19	◑	○	◔	⊗	◔	⊗	⊗	⊗	⊗	Low
20	◑	◔	◔	⊗	◔	⊗	⊗	⊗	⊗	Low
Wet Detention Pond										
21	◕	◑	◔	◔	◔	⊗	⊗	⊗	⊗	Moderate
22	◕	◑	◔	◔	◕	⊗	⊗	⊗	⊗	Moderate
23	●	◕	◑	◕	◕	⊗	⊗	⊗	⊗	High
Constructed Wetland										
24	◕	◑	◔	⊗	◑	◕	⊗	⊗	⊗	Moderate
25	◑	◑	◑	⊗	◑	⊗	⊗	⊗	⊗	Moderate
26	◕	◑	◑	⊗	◕	⊗	⊗	⊗	⊗	High

Key:	
○	0 to 20 % Removal
◔	20 to 40 % Removal
◑	40 to 60 % Removal
◕	60 to 80 % Removal
●	80 to 100 % Removal
⊗	Insufficient Knowledge

2.2.1 *Watershed Considerations*

The satisfactory use of individual BMPs on a given site can be limited by physical on-site and off-site factors. To be able to select cost effective, appropriate BMPs, each site must be carefully investigated and relevant characteristics identified. There is no standard set of BMPs that will work for every site development plan.

On-Site Factors

The first site-specific factor, and probably the most obvious, is site size. Small sites or high density sites may not have space available for some types of BMPs. Less obvious factors include seasonal high groundwater, and poorly drained soils.

Some of the most efficient and cost-effective practices encourage the infiltration of runoff into native soils. Unfortunately, some infiltration BMPs cannot be recommended in many areas of DuPage due to poorly drained soils and permanent or seasonal high groundwater elevations. In addition, DuPage's glacial drift soils often vary considerably across a site. Granular deposits (glacial till) in the form of lenses, seeps, and beds occur, often changing the drainage characteristics across a property. Other on-site factors affecting the selection of BMPs include slope, wetlands, ponds, riparian areas, and watercourses. Information on DuPage soils as they relate to infiltration practices can be found in Section 3.

Off-Site Factors

The location of the site within the watershed is the principal off-site factor to be concerned with when selecting BMPs. An investigation must be made of the surrounding land-use characteristics. The presence of nearby wetlands, lakes and watercourses all call for special attention as these are some of the primary aquatic resources in DuPage County that BMPs are ultimately intended to protect. As mentioned earlier, consideration must be given to the presence of nearby potable water wells. While DuPage County is largely serviced by water from Lake Michigan, there are still large areas where individual residences withdraw potable water from the shallow aquifer. BMPs that encourage stormwater infiltration have the potential to contaminate this shallow aquifer. The deep aquifer is also used in some areas of DuPage by municipalities as a backup or main water source. While not as vulnerable as the shallow aquifer, consideration must be given to infiltration practices within IEPA designated wellhead protection zones.

Weather

Northeastern Illinois experiences a significant period of cold weather as defined by an average daily maximum January temperature of <35F. In addition, the mean average snowfall in DuPage approaches 3 feet. Winter weather can compromise the performance of certain BMPs. Stormwater basins that are not constructed as part of a treatment train, and infiltration practices, can experience greatly reduced efficiency when frozen. Much research is currently underway to quantify the effects winter weather has on BMPs and some recommended design modifications have been published. Design modifications for winter weather have been incorporated into the BMP recommendations found in Section 3 of this manual.

2.2.2 *Impact Avoidance and Minimization*

Impact avoidance and minimization is one of the most important BMPs and also the most overlooked**.** The potential for pollutants to be introduced into stormwater can be minimized by following this simple procedure. This type of BMP, in return, can lower the overall cost of BMPs and other stormwater facilities required for site development. For example, eliminating unnecessary earth grading and compaction of soils will reduce the potential for erosion thereby reducing TSS (total suspended solids) and preserve the soil's infiltration capacity. Comprehensive stormwater land planning efforts that incorporate a suite of design practices such as reducing impervious surfaces, substituting swales for storm sewers, utilizing existing vegetated drainage ways, planting and preserving native vegetated areas, and incorporating wetland and riparian buffers can ultimately reduce both the potential for stormwater pollution, and the volume of stormwater runoff. This in turn can translate into a significant reduction in the cost of providing stormwater detention and BMPs. Table 2-3 summarizes the runoff reduction hierarchy that should be considered in impact avoidance and minimization.

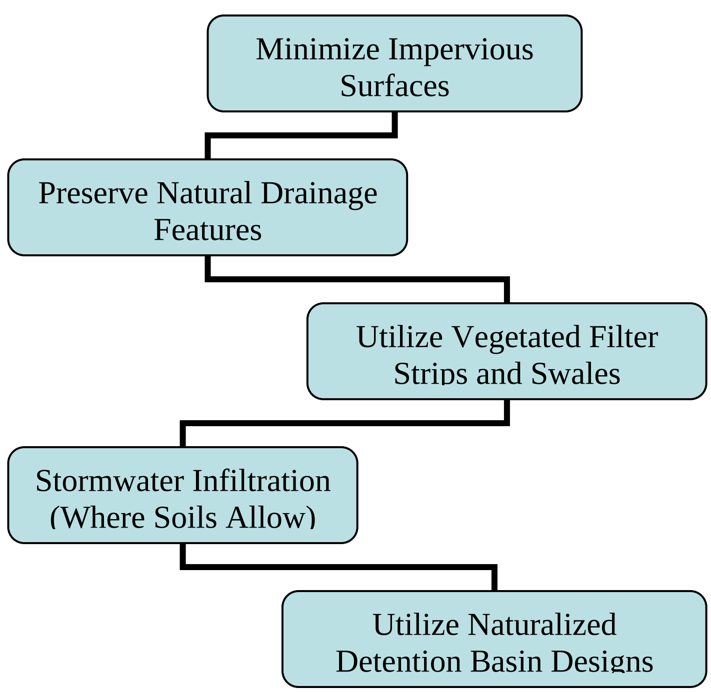
2.2.3 Maintenance and Easements

Possibly the second most overlooked BMP and again one of primary importance is **BMP maintenance and easement protection**.

Maintenance

Since the advent of modern stormwater management practices several decades ago, maintenance of constructed stormwater facilities has proven to be a difficult issue, especially for older facilities. Costs can exceed the responsible entities available resources and design inadequacies can result in facility failure. At their worst, both can produce hazards to public safety. With the implementation of the DuPage County Countywide Stormwater and Flood Plain Ordinance (DCSFPO) in 1992, many

Table 2-3
Runoff Reduction Hierarchy



stormwater facility maintenance (and easement protection) issues with land development such as identification of responsible parties and funding sources, were resolved. A summary of the DCSFPO maintenance requirements can be found in Section 3. With the exception of good housekeeping activities, BMPs require some level of maintenance. In meeting the goal of choosing cost effective and efficient BMPs, maintenance cost is an important issue. Table 2-4 shows groupings of BMPs by their relative construction and maintenance cost. In viewing this table, it quickly becomes apparent that there can be considerable variation in the maintenance cost between practices that provide similar benefits. For instance, vegetated swales and buffer strips have a much lower maintenance cost than structural BMPs such as sand filters and inlet devices. If existing vegetated swales and buffers can be preserved, the overall cost can be even lower. While maintenance cost should not always be a deciding factor in the selection of a BMP, choosing low maintenance BMPs, where feasible, is strongly encouraged.

<u>Easements</u>

Maintenance will likely lapse if funding is inadequate and/or legal provisions have not been made to protect permanent BMPs and provide for their access and maintenance. As physical BMPs are by definition *stormwater facilities* in the DCSFPO, new land-use development is required to provide certain provisions for funding, and short and long-term maintenance as part of obtaining a Stormwater Management Permit.

Table 2-4
BMP Cost & Maintenance Requirements vs. Effectiveness

	BMP	COST	MAINTENANCE	POLLUTANT REMOVAL				
				Nitrogen	**Phosph.**	**TSS**	**Metals**	**Oil**
1	Dry Bottom Detention	High	Moderate	Low-Med	Low-Med	Med-High	Low-Med	**
2	Wet Bottom Detention	High	Moderate	Med	Med	High	Low-Med	**
3	Wet Bottom Detention w/ Wetland Filtration	High	Moderate	Med-High	Med-High	High	Med-High	**
4	100% Wetland Vegetated Detention	High	High	*	*	High	Med-High	High
5	Vegetated Swales	Moderate	Low	Low-Med	Low-Med	Med-High	Low-Med	**
6	Filtration Strips	Moderate	Low	Low-Med	Low-Med	Low-High	Low-High	**
7	Infiltration Practices	Moderate	High	Med	Med-High	High	Med-High	**
8	Filtered catch basins	High	High	Low	Low	Med-High	**	High
9	Permeable Pavement	High	Low	Med-High	Med-High	Med-High	Med-High	High
10	Standard Catch Basins	Low	Low	**	Low	Low-Med	Low	**

* Varies
** Insufficient Information

Source: adapted from DuPage County,2001 and ASCE, 2001

Section 3

Best Management Practices (BMPs)

Conventional vs. Conservative Subdivision Layouts
Source: (Blackberry Creek Watershed Alternative Futures Analysis Project, Kane County, Illinois)

3.1 Introduction

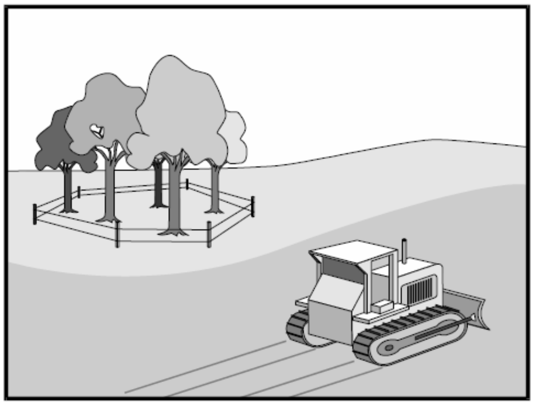
In the previous section, information was provided to assist with the selection of BMPs based on targeted pollutants and physical site constraints. In this section design details, commentary on specific BMPs appropriate for DuPage County, performance comparisons, costs, and a selection guide based on land-use are presented.

3.2 BMPs for Stormwater Runoff

Stormwater runoff is produced when it rains. While this is a simple statement to make, the reality of the situation is a bit more complex. Runoff, or conveyance of stormwater, varies greatly depending on factors such as the type of surface that raindrops fall on and the amount and intensity of the rain. With site-specific BMP selection, site size plays an important role as larger sites produce greater volumes of stormwater runoff. Conveyance BMPs are activities that treat or reduce stormwater pollutants in stormwater runoff. Examples include: reducing the rate and volume of runoff by minimizing and disconnecting impervious surfaces; and providing setbacks for impervious surfaces from high quality aquatic resources. Other conveyance BMPs include the design and construction of on-site filtration and infiltration practices. Conveyance BMPs are applicable to small sites that fall below stormwater detention requirement thresholds (such as single family homes and recreational open space); as practices to retro-fit existing land uses and activities, and as part of the "treatment train" utilized for the overall pollution control plan for larger sites.

3.2.1 Avoidance and Minimization

As discussed in Section 2, this manual strongly recommends avoidance and minimization as a high priority BMP. With regard to treating stormwater runoff for pollutants, avoiding and minimizing activities that cause pollutants to become entrained in



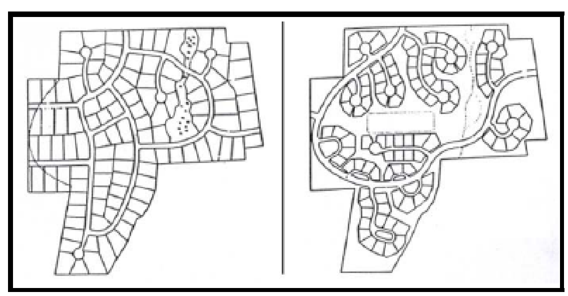
stormwater runoff is a cost effective, efficient step to take in striving towards the ultimate goal of discharging clear stormwater, free from natural or man-made pollutants. Some common conveyance avoidance and minimization activities to be considered in site planning are:

1. **Minimizing the area of disturbance**. Examples include but are not limited to:

- Performing earthwork in phases instead of mass grading. When compared to mass grading, this practice reduces the site's runoff volume and velocity and can also reduce the size and magnitude of the sediment and erosion control practices necessary to control the site. As a result, the risk of discharging sediment laden stormwater is lessened;

- Avoid grading the entire site. In many cases, the undisturbed native soil profile encourages infiltration without any effort aside from restrictions on construction access and disturbance. Compaction of soil must be avoided to utilize this type of BMP. Preserving the native soil profile and vegetation in areas that are to be designated as open space and eliminating unnecessary grading can preserve infiltration capacity which will reduce the total stormwater runoff volume required to be treated through BMPs. Minimizing disturbance has the added benefit of reducing the amount of detention required. Planting deep-rooted native vegetation or managing an existing native community may be less costly and time consuming than in areas with disturbed or compacted soils;

- Reduce zoning density through clustering development (See Figure below). Concentrating density into clusters can result in decreased permanent and temporarily disturbed area, which reduces runoff volume and velocity of the completed development. Efforts to protect open space from disturbances during development also aid in preserving infiltration capacity consequently reducing the total stormwater runoff volume required to be treated through BMPs. In turn, cost and magnitude of permanent BMPs and stormwater detention may be reduced;



Conventional vs. Grouped Lot Design
From J. Lacy (1990), Reprinted in NIPC, 1997a

- Maintaining Native Vegetated Open Spaces. An area open space that is a minimum of 25 feet in width shall be maintained or established adjacent to Waters of DuPage where the riparian environment or buffer is not present or is less restrictive than 25 feet. The ground cover in this area shall be native, non-invasive vegetation. Enhancement of an existing special management area may be considered a BMP where no enhancement would be proposed as enhancement for impacts to Special Management Areas caused by development. Maintaining or establishing natively vegetated open spaces that are not considered a Special Management Area under the DCSFPO may also serve as an appropriate BMP. These areas will be reviewed on a case by case basis.

2. **Minimize the runoff rate and volume**. A reduction in the cost and magnitude of required BMPs can be realized through minimizing runoff rates and volumes. Examples include but are not limited to:

- Avoiding the use of storm sewers where possible. Substituting vegetated swales and overland flow routes for storm sewer slows the rate of stormwater runoff and multiplies the water quality benefit realized through the use of vegetative filtration;

DuPage County backyard swale

- Disconnect impervious surfaces from the storm sewer system. In conjunction with limiting the use of storm sewers, avoid direct connections of impervious surfaces to storm sewers through the use of filter strips, swales, settling basins, constructed wetland, etc;

- Minimizing impervious surfaces through practices such as utilizing permeable paving surfaces (See below photos for examples); avoiding unnecessary pavement and parking; reducing street widths and building setbacks and avoiding unnecessary compaction during the construction process. These practices will reduce the runoff volume and velocity of the completed development or can be used to retrofit existing developments which can reduce the cost and magnitude of required BMPs;

Blackberry Creek Watershed Alternative Futures Analysis Project

3.2.2 Conveyance BMPs

This section concentrates on the application and design of the following BMPs:

- Vegetated Filter Strips
- Vegetated Swales
- Infiltration Practices
- Permeable Pavers
- Manufactured BMPs

When designing conveyance practices utilizing native vegetation, it is imperative that early interaction between landscape architects/ecologists and project architects, engineers, and site planners takes place.

DuPage County
Best Management Practices Manual
Practice Standard

3.2.2.1
VEGETATED FILTER STRIP

Draft Pennsylvania Stormwater Management Manual

Definition:

Filter strips, also know as vegetated buffer strips, are vegetated sections of land that are essentially flat with low slopes, and function best when runoff is accepted as overland sheet flow (Schueler, 1992).

Purpose:

Filter strips reduce runoff and waterborne pollutants by routing runoff over permeable vegetated areas. Runoff is slowed allowing more stormwater to infiltrate the soil as it flows through rough or stiff (native) vegetation, allowing more stormwater to infiltrate the soil. When installed correctly, filter strips can be effective at filtering certain pollutants and can also reduce the volume of surface runoff leaving the site. When used to disconnect impervious areas, filter strips provide both rate and volume control.

Reduction of runoff rate is achieved by increasing the length of time it takes water to reach stormwater management facilities and drainage infrastructure such as: ditches, streams, lakes, and wetlands. Infiltrating runoff into the soil reduces runoff volume.

Waterborne pollutants are reduced through vegetative filtering and encouraging runoff to infiltrate the soil. Total suspended solids (TSS) and metals are reduced when they are allowed to settle out as the rate of flow slows. Dissolved pollutants such as nutrients, BOD, and organic matter are removed or transformed as water is allowed to seep into the soil.

Effective natively vegetated filter strips can range from short to tall stature prairie grasses and forbs, to second growth forest. Filter strips used as a BMP may double as an aesthetically pleasing buffer between buildings, other developments, and Special Management Areas. Filter strips can preserve the character of riparian areas, prevent erosion, and provide urban wildlife habitat (Schueler, 1992). They can work alone or in conjunction with other BMPs in a treatment train.

Runoff Reduction:

Due to their infiltration capabilities, filter strips may also contribute to ground water recharge (Schueler, 1987). Filter strips are more effective at reducing runoff when the impervious drainage area is not large (i.e. not greater than 2-3 times as large as the filter strip). As the soil becomes saturated, its capacity to infiltrate lessens; therefore, filter strips are more effective in reducing volumes in small storm events, up to the 1- to 2- year events. Runoff volumes in these small events could be reduced by as much as 40% by turf filter strips and up to 65-70% if the strip is vegetated with deep rooted prairie vegetation. Deep-rooted vegetation increases the permeability of the soil, which results in more efficient infiltration. Therefore, filter strips used solely for runoff purposes can be incorporated into residential lawns and areas immediately adjacent to commercial and industrial buildings and, when used in addition to natively vegetated buffers, between the development and special management areas. Trees and shrubs within filter strips also provide a stormwater management benefit by intercepting rainfall before it reaches the ground, and improving infiltration and retention through the presence of a spongy, organic layer of materials that accumulate beneath the plants (Schueler 1987). Filter strips cannot treat high velocity flows, and do not provide enough storage or infiltration to effectively reduce peak discharges to pre-development levels for design storms (Scheuler 1992). As filter strips are more effective in small events, stormwater management must still be provided in accordance with the DCSFPO.

Runoff Pollutant Reduction:

Filter strips may remove up to 70-90% of TSS and metals while dissolved pollutants may be removed up to 25-65% if the flow is not concentrated. Pollutant removal efficiencies for vegetated filter strips are shown in Table 3-1. Vegetation should be chosen that is compatible with the pollutant expected and provides the desired runoff reduction; while good clean top soil is essential for all filter strips. Conventional turf grasses generally provide a lower removal rate for TSS as they have a tendency to lay down when water flows over them and also generally do not provide a reduction in Nitrogen and Phosphorus as grass clippings and chemical fertilizers, often applied to achieve optimal growth, contribute to these pollutants. **Therefore, conventional turf grasses are not suitable as a pollutant reduction BMP.** Research is unclear on whether native grassed or forested filter strips are more effective at removing pollutants. Organic matter on forest floors can absorb pollutants effectively; however, most forested areas do not have dense vegetation at the soil substrate needed to reduce runoff rates, essential to remove suspended solids (Schueler 1987). Therefore, care must be taken to establish a shade tolerant herbaceous layer in wooded systems or design a longer filter strip to achieve the same detention time.

Table 3-1
Pollutant Removal Efficiencies for Selected Filter Strip Designs

Pollutant Constituent	Turf Filter Strip (6 m [20 ft] length)	Forested Filter Strip (30 m [100 ft] length)
Suspended Sediment	20-40%	60-80%
Total Phosphorus	>20%	40-60%
Total Nitrogen	>20%	40-60%
Trace Metals	20-40%	>80%*
Biological/Chemical Oxygen Demand	>20%	60-80%

*Removal rates for trace metals associated with particulates.

Winter operation is variable and snow melt or rain on frozen ground cannot be treated effectively by a filter strip. Other water quality options should be explored to provide a backup to filter strips during the winter when their pollutant removal ability is reduced. In addition, soluble inorganic compounds, such as road salts, are generally not removed by soil and vegetation.

Site Considerations:

Filter strips can be used adjacent to impervious areas, up gradient from watercourses, wetlands, or other water bodies, and at outlets of stormwater management structures. The most critical design constraint is achieving and maintaining sheet flow over the filter strip; therefore, if sheet flow is not present, a level spreader or multiple discharge points is required. Please see below for proper level spreader design techniques.

Contributing Area:

- Filter strips function best when the contributing area is 5 acres or less; therefore, runoff should be directed in different directions to optimize the filter strip width or multiple strips can be used for large impervious areas.
- The minimum length of the filter strip may be determined by the type of vegetative cover, permeability of the soil present, and slope of the filter strip.

Vegetation:

The vegetation used for the filter strip can range from indigenous grasslands to woods.

- Vegetation that is best suited to remove the pollutant expected and provides the desired runoff reduction should be chosen.
  - ➢ Vegetation should be dense at the soil interface. Examples of appropriate species available from the NRCS and example seed mixes for vegetated filter strips are provided in Appendix 4.3.
  - ➢ Native herbaceous and woody plantings are preferred over conventional turf grass due to their improved ability to filter pollutants, tolerance for wet conditions, resistance to erosion, and reduced need for maintenance. Therefore, using conventional turf grasses should be avoided.

- Planting lists using native species can be formulated with height in mind.
  - ➢ Taller species are preferred where the velocity of runoff is

"Blackberry Creek Alternative Futures Analysis"

expected to be high due to the plants increased roughness.

- ➢ A roughness coefficient of approximately 0.25 to 0.30 is often appropriate for sheet flow through a filter (USDA-SCS 1984).
- ➢ Prairie forbs provide wildlife habitat value and color that is aesthetically pleasing.
- ➢ Short stature prairie grasses and forbs may be appropriate where slower flows are expected.
- ➢ Acceptance of native vegetation will always come down to personal aesthetics; however, it is important to remember that any area that is neglected or not properly maintained will look weedy or messy. Therefore, proper installation and maintenance of native vegetation is essential.

- When a filter strip is to be incorporated into an existing riparian area or wetland buffer, care should be taken to eliminate disturbance to existing screening, shading, and wildlife habitat functions associated with woody vegetation.
  - ➢ Vegetation in native wooded areas is not as dense as that of open prairie areas. Wooded filter strips may need additional length to accommodate more vegetation. In areas where a thick over story is present, shade tolerant species should be used to maintain dense vegetation at the soil substrate to slow runoff velocity and remove suspended solids.
  - ➢ Management of non-native/invasive plants will allow for ambient light to reach the forest floor so a thick herbaceous layer remains to filter pollutants.
  - ➢ Tree and shrub trunks may cause an uneven distribution of flows, consequently requiring flatter slopes to ensure that the presence of large plant stems will not facilitate channelization. However, surface features that slow runoff flow, cause ponding, and/or disperse runoff are acceptable.
  - ➢ Removal of vegetation in Special Management Areas may require a Stormwater Permit.

- As salt is used on many impervious areas as an ice melting medium during winter months, it may be appropriate to add some salt tolerant species to a planting plan. These specialized plant mixes can be salt tolerant and effective at removing sediments if they are not mowed. Please note road salts generally cannot be removed by soil or vegetation.

The above referenced vegetation types for the purposes of TSS removal have been divided into categories based upon their height and ability to slow runoff. Table 3-2 illustrates these categories:

Table 3-2

Growing Season Vegetal Retardance Factors*		
Retardance	**Cover**	**Condition**
A Very High	Trees and Brush Cattail, River Bulrush, Hard-stem Bulrush Native Tall Prairie	Excellent Stand (>30”)
B High	Native Low Profile Prairie	Good Stand (18”-30”)
C Moderate	Short Stature Prairie Salt Tolerant Roadside Mix	Good Stand, (6”-18”)
D Low	Buffalo Grass Fescue Mixes Kentucky Blue Grass	Good Stand, Unmowed (3”-6”)
E Very Low	Buffalo Grass Fescue Mixes Kentucky Blue Grass	Good Stand, Mowed (<3”)

*For turf and other low growing grasses, a dormant season retardance factor of one less than the growing season factor should be used. For native vegetation and other tall growing vegetation mowed or burned in the fall, a dormant season factor two less than the growing season factor should be used. *Adapted from the Natural Resource Conservation Service (NRCS)*

Length:

The required filter strip length is also based upon the hydrologic soil group or permeability of the soils throughout the strip.

- Hydrologic Soil Groups are used to estimate runoff from precipitation based upon the intake of water after the soil has been wetted and has received water from long duration storms.
- Where more than one soil type is present within the filter strip area then the soil with the smallest particle size shall be used to determine the filter strip length and slope. This is to account for the lower permeability rate of tighter soils.
- The type of vegetated cover and soil present can determine the maximum allowable slope for a vegetated filter strip.
- Slopes for filter strips between 2-5% are preferred, but can be up to 10% and should be uniform throughout to encourage sheet flow.

Table 3-3 identifies the maximum allowable slope for various vegetated cover and soil type:

Table 3-3

Required Slope as a Function of Soil and Coverage Type Table			
Filter Strip Soil Type	Hydrologic Soil Group	Maximum Filter Strip Slope (Percent)	
		Turf Grass, Native Prairie Vegetation	Planted and Indigenous Woods
Sand	A	7	5
Sandy Loam	B	8	7
Loam, Silt Loam	B	8	8
Sandy Clay Loam	C	8	8
Clay, Silty Clay, Silty Clay Loam	D	8	8

Adapted from the New Jersey BMP Manual (2004)

Based upon the above referenced criteria, the filter strip length can be determined by the following figures. As shown in the figures, the minimum length for all vegetated filter strips is 25 feet.

Figures 3-1 through 3-4
Required Length as a Function of Slope, Soil and Coverage

Adapted from the New Jersey BMP Manual (2004)

Figure 3-1
Drainage Area Soil: Sand HGS: A

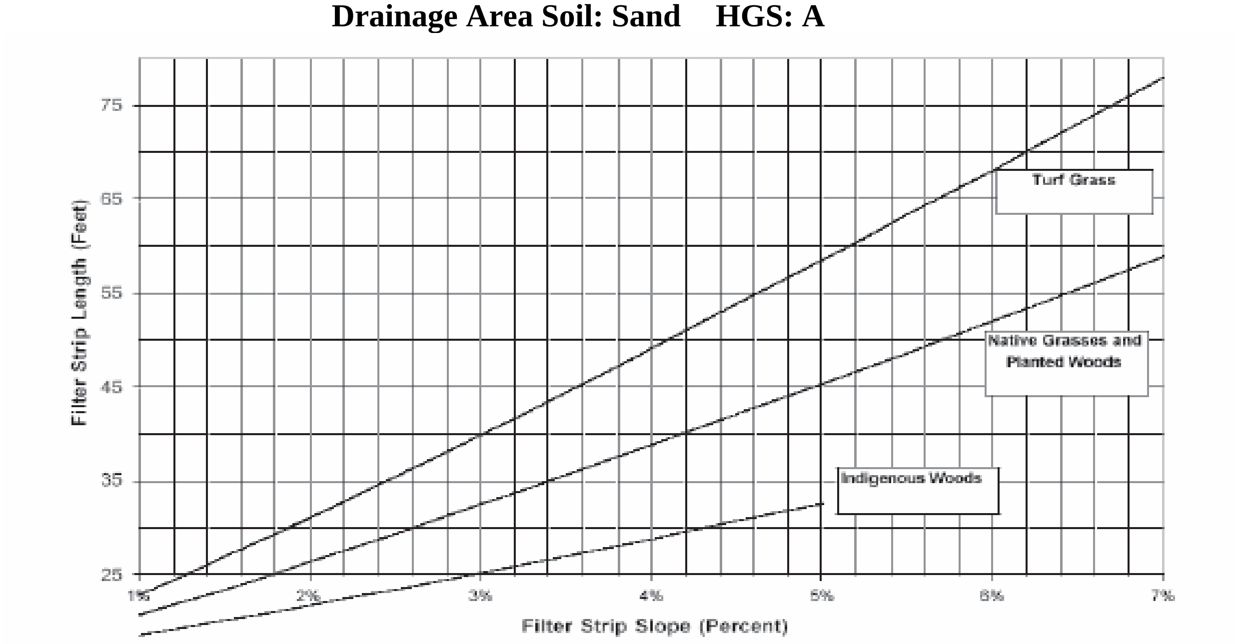


Figure 3-2
Drainage Area Soil: Sandy Loam HGS: B

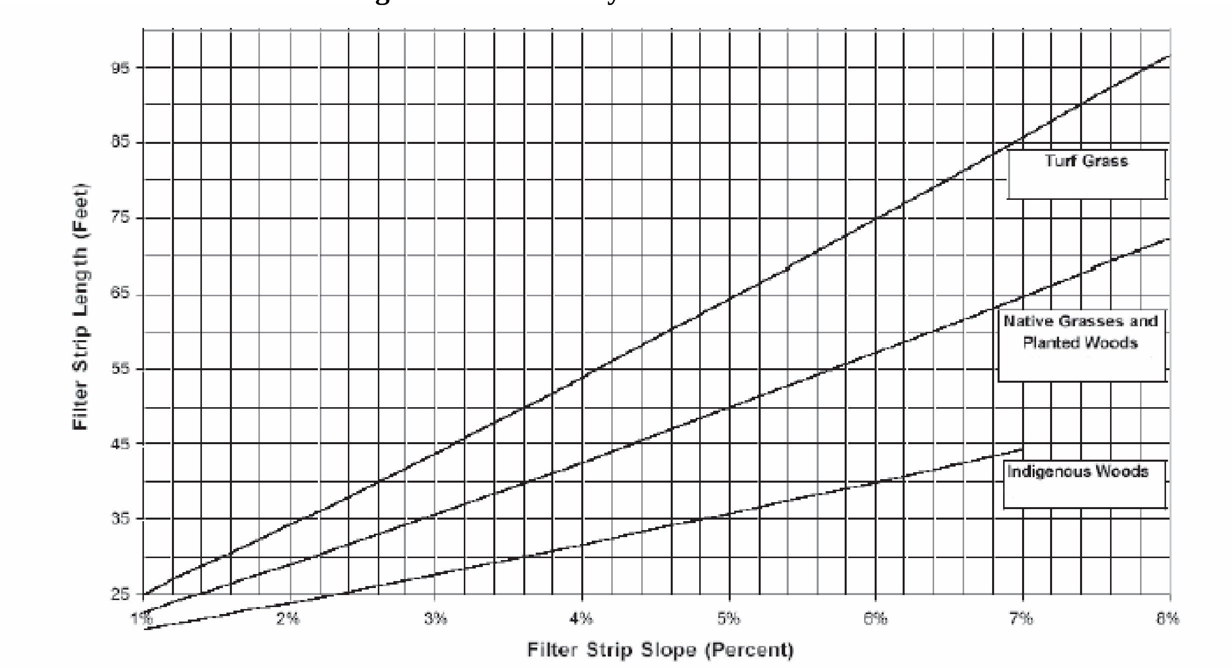


Figure 3-3
Drainage Area Soil: Loam, Silt Loam HGS: C

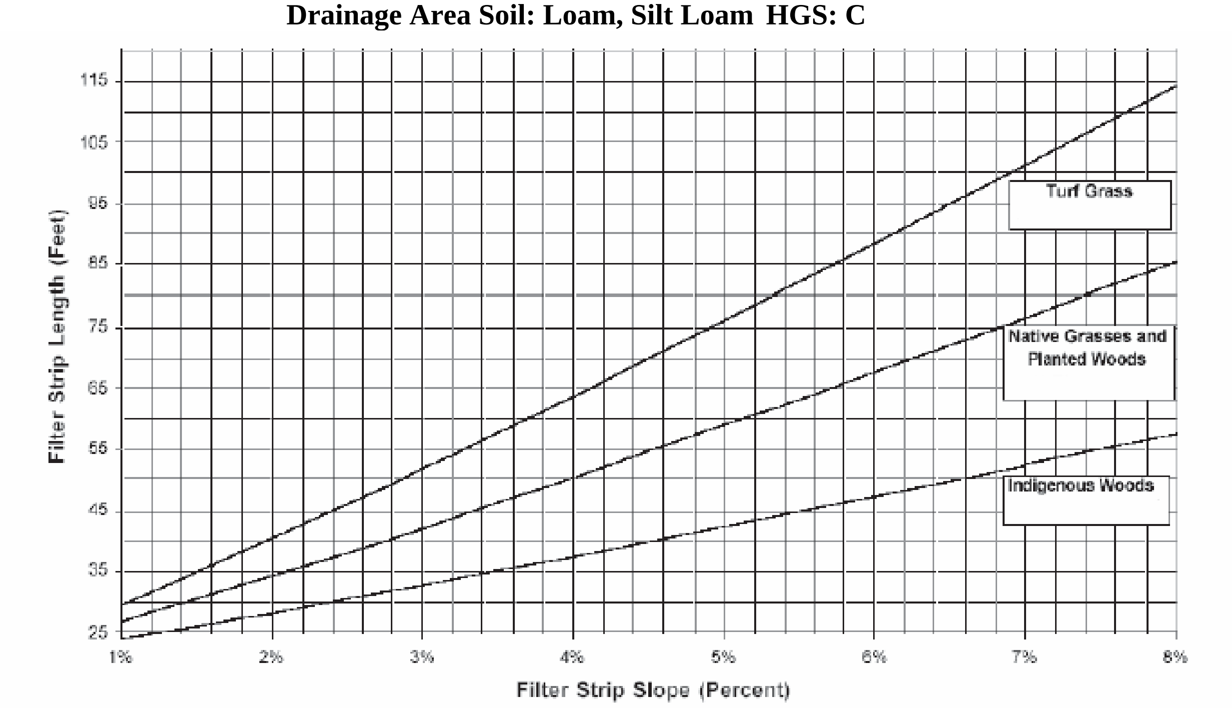
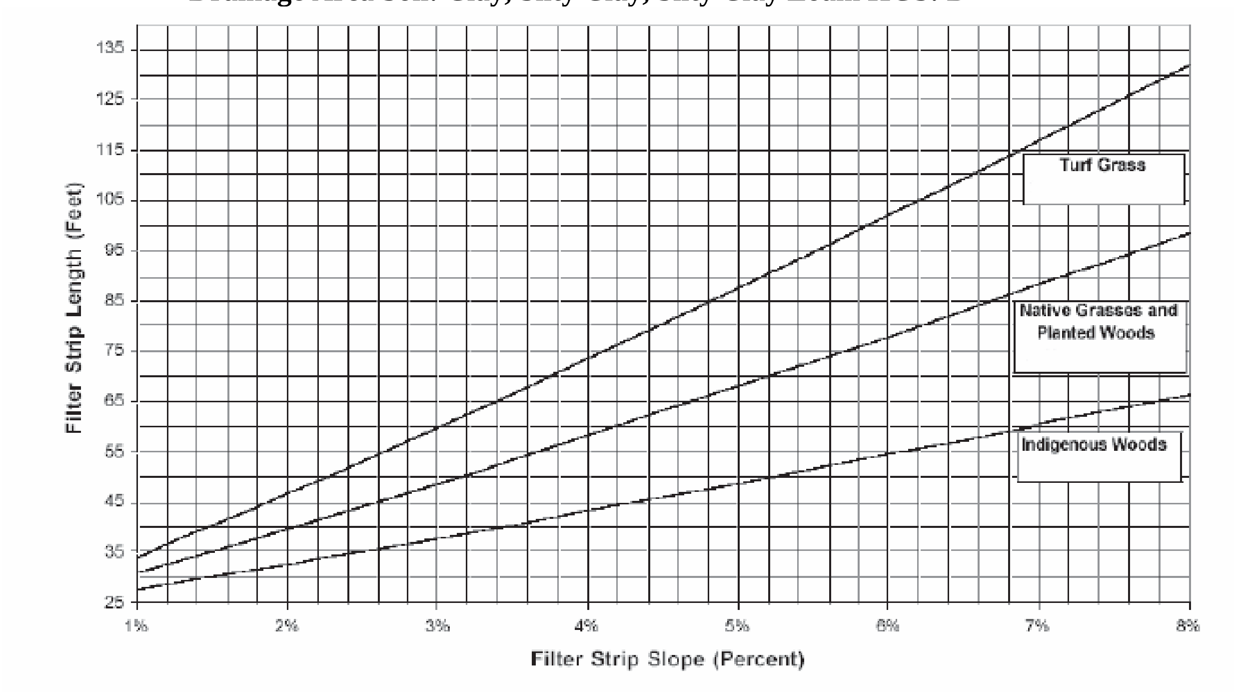


Figure 3-4
Drainage Area Soil: Clay, Silty Clay, Silty Clay Loam HGS: D



Filter strips should not be greater than 100-150 ft in length as sheet flow over time begins to concentrate and cause erosion. Hydraulic residence time should not be less then 9 minutes and in no case less than 5 minutes.

The average depth of flow should be no greater than 0.5in during the water quality storm (2-yr event 3.04" in 24 hour duration).

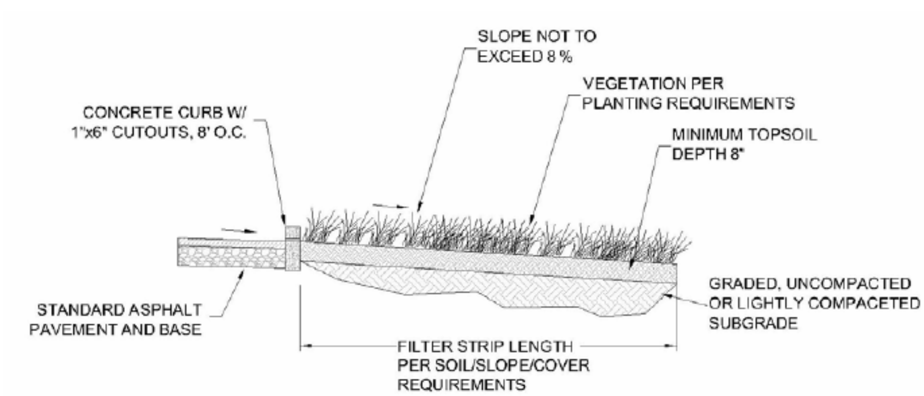


Figure 3-5 Pennsylvania Stormwater Management Manual

Level Spreaders:

Level spreaders are often required at the top of the slope to distribute concentrated runoff evenly across the entire length of the filter strip. Concentrated flows entering a filter strip can cause erosion and lead to the failure of the system.

- The out flow and filter side lip of the spreader should have a zero percent slope to ensure even runoff distribution (Yu and Kaighn 1992).
- The last 20 ft of the channel or pipe preceding the level spreader should not exceed 1% so as to provide a smooth transition to the level spreader.
- Many level spreader design variations exist, including: a gravel filled trench, a concrete sill or lip, curb stops, slotted or depressed curbs, and naturalized earthen berms installed along the entire up gradient of the filter strip.
  - ➢ Gravel filled trenches are typically 12" wide, 24-36" deep, lined with a non-woven geotextile filter fabric, and filled with pea gravel approximately 1/8" to 3/8".
  - ➢ A 1-2" drop is recommended when the trench is placed directly adjacent to the impervious surface to inhibit the formation of the initial deposition barrier (Pennsylvania Stormwater Management Manual).
  - ➢ Runoff from rooftops and curbed impervious areas should be directly conveyed to the trench via pipe into the subsurface gravel and uniformly distributed via perforated pipe along the trench bottom.
  - ➢ The bottom of the trench should be below the frost line to prevent water from freezing.
  - ➢ If a perforated pipe is proposed in the trench, it should be at least 8" wide to discourage freezing.

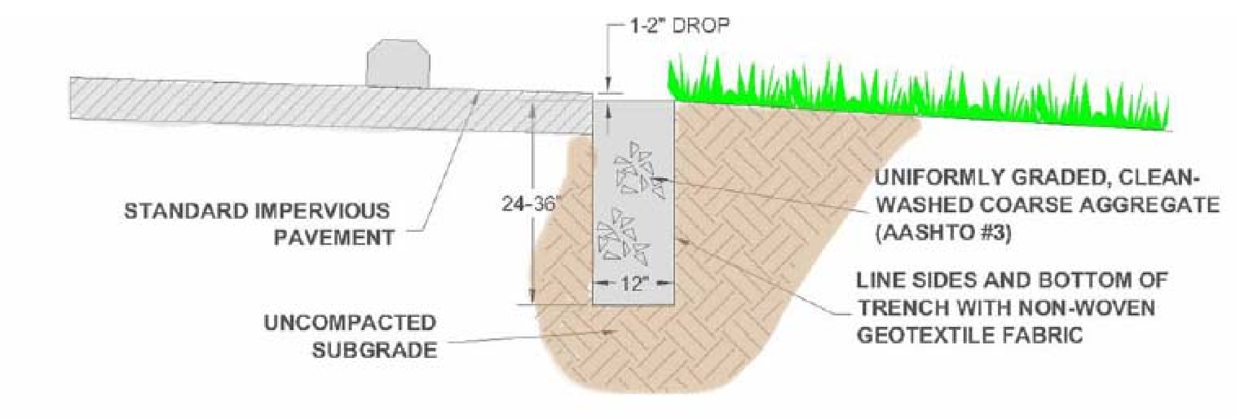


Figure 3-6 Pennsylvania Stormwater Management Manual

Installation of level spreader at Coffee Creek Watershed Preserve

Maintenance Procedures:

Required maintenance depends on the type of vegetation chosen and on whether the natural vegetative succession is allowed to proceed.

- Vegetative succession is the gradual transformation from grass to meadow to second growth forest. This transformation will enhance rather than detract from the performance of longer filter strips (Schueler, 1987). If vegetative succession is allowed to proceed, maintenance of the 2nd growth forest must be performed to remove non-native/invasive plants and allow for ambient light to reach the forest floor so a thick herbaceous layer remains to filter pollutants.
- Maintenance of newly planted prairie is intensive for the first 3 years. Initial maintenance often involves regular herbicide applications to kill non-native or weedy species and allow planted material to compete. If installed and maintained correctly, prairie-type filter strips should require very little subsequent management. To maintain a prairie condition, the filter strip should be burned once a year for the first three years and subsequently every other year for even germination and to promote deep root growth. However, it is important to note that prairie plantings often cannot be burned until the third year due to the lack of fuel, root establishment, and melting blanket. In such cases, other maintenance procedures such as a prescribed mowing schedule, weed whipping, and selective herbicide are more appropriate.
- Minimum planting diversity standards, maintenance procedures, and performance standards should be in accordance with Appendix 4.4**.**

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DuPage County
Best Management Practices Manual
Practice Standard

3.2.2.2
VEGETATED SWALE

Blackberry Creek Watershed Alternatives Analysis Project

Definition:
Vegetated swales are broad, shallow, earthen channels designed to slow runoff, promote infiltration, and filter pollutants and sediments in the process of conveying runoff (Pennsylvania BMP Manual, 2005).

Purpose:
Vegetated swales reduce runoff and waterborne pollutants by providing an opportunity for runoff from impervious areas to pass over permeable vegetated areas. Runoff volume is reduced by encouraging runoff to infiltrate the soil, while waterborne pollutants are reduced through vegetative filtering. The degree to which the swale is effective is closely related to the height and roughness of the vegetation relative to the depth of the flow. Several types of vegetated swales will be discussed in this section, including: native vegetated swales, vegetated swales with infiltration trenches, grass swales, wet swales, and bio swales.

A typical swale design provides a water quality benefit and often costs less than curb and gutter or underground storm sewer systems. The natural features of a site may be preserved when swales are incorporated into the site's natural topography. Swales are best suited for use in low flow and small population residential, industrial, and commercial areas. Vegetated swales can work alone or in conjunction with other BMPs in a treatment train.

Runoff reduction:
Vegetated Swales provide both reduced rate and volume as compared to storm sewer systems. Runoff rate is reduced because vegetated swales provide a greater resistance to flow in addition to design features, such as undersized

culverts and check dams. Runoff volume is reduced by encouraging stormwater to seep into the soil.

Swales constructed with an underlying aggregate base provide additional runoff volume reduction and a further reduced stormwater conveyance rate. Due to their infiltration and runoff rate reduction capabilities, vegetated swales may be effective at reducing the flashiness of small storms that causes erosion of urban stream banks and disruption of wildlife (Price 1994). An analysis in Lake County by Price indicates that runoff volumes could reduce annual stormwater runoff volumes by as much as 15% if vegetated swales are conservatively designed and properly maintained. Vegetated swales cannot treat volumes greater than the 10-year event and/or high velocity flows due to the erosive abilities of these storms. Therefore, as vegetated swales are more effective in small events, stormwater management must still be provided in accordance with the DCSFPO. Trees and shrubs along the side slopes of a vegetated swale also provide a stormwater management benefit by intercepting some rainfall before it reaches the ground (Schueler 1987).

Runoff Pollutant Reduction: The waterborne pollutant removal mechanisms of a swale include: filtering of runoff and reduction of flows where vegetation with a high roughness value is planted, filtering through a sub soil matrix, and infiltration into the underlying soils. Total suspended solids (TSS) and metals are reduced by settling due to the slowed runoff rate. Dissolved pollutants such as nutrients, BOD, and organic matter are removed or transformed as water infiltrates into the ground. Based upon studies by Barret, et al, 1993, Schueler 1991; Yu, 1993; and Horner 1993 TSS may be removed up to 70%, while dissolved pollutants may be removed up to 25%, and up to 70% for trace metals if the swale is designed correctly and well maintained. Yousef, et al., 1985, determined negative nitrogen removal in many cases, this may be due to grass clippings and other organic materials present in swale systems. Conventional turf grasses when used in a vegetated swale generally provide a lower removal rate for TSS as they have a tendency to lay down when water flows over them. Table 3-4 provides the percentage of pollutant removal efficiencies for two vegetated swale lengths for the above referenced studies (BMP Guide).

Table 3-4

Pollutant Removal Efficiencies for Vegetated Swale Designs

Pollutant Constituent		Pollutant Removal Efficiencies (%)	
		61 m (200 ft) length	30 m (100 ft) length
Solids	TSS	83	60
Nutrients	Total Nitrogen	25*	*
	Total Phosphorus	29	45
Trace Metals	Zn	63	16
	Pb	67	15
	Cu	46	2
Other	Oil & Grease	75	49
	Chemical Oxygen Demand**	25	25

*Some swales, particularly 100 ft systems, showed negligible or negative removal for TN.
**Data is very limited.

Winter operation is variable and snow melt or rain on frozen ground cannot be treated effectively by a vegetated swale. Other water quality options, such as a sediment forebay or plunge pool, should be explored to provide a backup to vegetated swales during the winter when their pollutant removal ability is reduced or if high velocities are proposed. In addition, soluble inorganic compounds, such as road salts, are generally not removed by soil and vegetation.

Site Considerations:

Vegetated swales are defined as broad, shallow, earthen channels designed to slow runoff, promote infiltration, and filter pollutants and sediments in the process of conveying runoff. A vegetated swale consists of a band of dense vegetation, underlain by at least 30in of permeable soil.

Contributing Area:

Vegetated swales are primarily stormwater conveyance systems that can provide sufficient water quality treatment under light to moderate runoff conditions.

- Swales are best suited for use in low flow and small population residential, industrial, and commercial areas and roadway drainage.
- Vegetated swales are typically located along property boundaries or within the natural grade; however, they may be used wherever adequate space and design standards are able to be met.

Vegetation:

Swales can be vegetated with native plants or conventional turf grasses.

- Swales vegetated with native dense diverse close growing water resistant vegetation often have a higher potential for pollutant removal than conventional turf grasses as their height and vegetal retardance is higher. As conventional turf grasses have a tendency to lay down when water flows over them they generally provide a lower removal rate for TSS; therefore, native vegetation should be used wherever possible.
- If conventional turf grasses are proposed, the vegetated swale should only be used as pretreatment in conjunction with other BMPs in a treatment train.
- Minimum planting diversity standards, maintenance procedures, and performance standards should be in accordance with Appendix 4.4.

Retardance factors for use during the growing season are provided in Table 3-2.

Slope:

Swales with parabolic and trapezoidal cross-sections function best due to their ease of construction and maintenance, reduced scour potential, and enhanced pollutant removal (NIPC).

- To maximize the wetted perimeter, side slopes of 4:1 or flatter are recommended. Side slopes should not exceed a 3:1 ratio. If space is available side slopes less than a 4:1 ratio are encouraged.
- Longitudinal channel slopes varies within the literature between a swale slope as close to zero as drainage permits and 4%. Slopes greater than 4% can be used if check dams are used to reduce flow velocity.

- Flatter slopes minimize velocity and therefore improve pollutant filtering capabilities.

Width:
The width of the swale can be determined using various forms of the Manning equation or by the following rule of thumb: the total surface area of the swale should be one percent of the area (approximately 500 square feet for each acre) that drains to the swale.

- The bottom width should be no less than 2 ft and no greater than 8 ft to prevent scour and meander across the bottom.
- Wider swales may be used when obstructions such as berms are employed to prevent low flow meander formation.
- The depth of the flow in the swale is determined by the longitudinal slope, side slopes, bottom width, vegetation and design flow rate.
- Lower velocity will tend to enhance pollutant removal, while shallower depths will result in lower velocities.
- Utilizing tall native vegetation, as discussed above, will increase the size of the event that can be conveyed at flow depths less than the height of the vegetation.

Capacity:
- Swale dimensions must convey the water quality storm (typically the 3.04" 24-hour event over the drainage area) at 1 ft/second, no deeper than the vegetation proposed as it could cause the vegetation to bend over with the flow. This would lead to reduced roughness of the swale, higher flow velocities, and reduced contact filtering opportunities (Penn BMP).
- The swale must also convey ten-year 24-hour storm at a maximum of 7 ft/sec.
- If the maximum permissible velocity is exceeded under design flow conditions, the vegetal retardance should be increased, the bottom width enlarged, the side slopes flattened, or check dams used to reduce the effective longitudinal slope to decrease the velocity.

Design Variations in Vegetated Swales:

Several design variations, which will be discussed in this section, meet the requirements to be classified as a vegetated swale, including: vegetated swales with infiltration trenches, wet swales, turf swales, and bio swales.

Vegetated Swales with Infiltration Trenches:
Swales constructed with an underlying 12 to 24 inch aggregate layer provide significant volume reduction and reduce the stormwater conveyance rate. The permeable soil media should have a minimum infiltration rate of 0.5 inches per hour and contain a high level of organic material to enhance pollutant removal. The aggregate within the trench shall be wrapped by a non-woven geotextile material.

Please see the following example design guidelines (Pennsylvania Stormwater Management Manual):

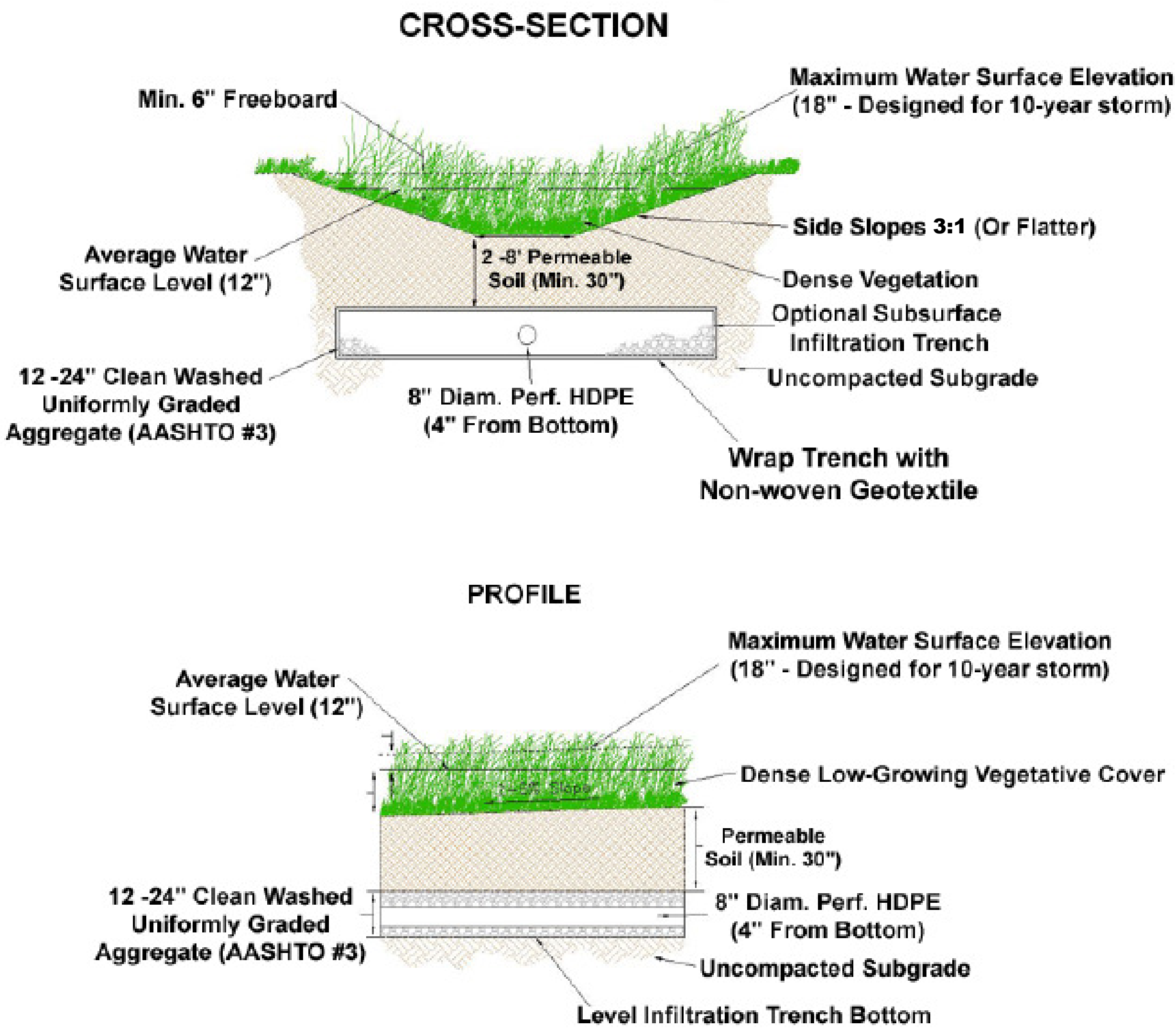

Figure 3-7 Vegetated Swale with Infiltration Trench
(Pennsylvania Stormwater Management Manual)

<u>Wetland Vegetated Swales</u>:
A wetland swale is a linear area that incorporates shallow, temporary or permanent pools, or marshy areas that can support wetland vegetation. Wetland swales provide significant pollutant removal. Soils within wetland swales must be poorly drained. Wetland swales can be utilized within commercial and industrial developments adjacent to parking, along roads and

Wetland Vegetated Swale
Blackberry Creek Watershed
Alternatives Analysis Project

highways, within residential subdivisions, as an alternative to conventional curb and gutter storm sewer systems, and as a pretreatment for other BMPs.

Turf Swales:
A grassed swale is a conventional means of directing drainage through residential subdivisions typically located between residences along property lines. Grassed swales do not provide the pollutant and rate reduction opportunities that native vegetated swales provide. Therefore, they should only be used as pre-treatment in conjunction with other more effective BMPs. However, grassed swales are preferred over catch basins and storm sewer as they provide some rate reduction benefits.

Residential Area Vegetated Swale (Virginia Stormwater Management Manual)

Bio Swale:
A bioswale is a conveyance structure that uses a bioretention media beneath the swale to improve water quality, reduce runoff volume, and peak runoff rates. The bioretention media provides enhanced infiltration, water retention, and nutrient and pollutant removal. Bioswales are a preferred treatment for parking lot runoff. A bioswale can treat the first ½ inch of rainfall off of a paved surface. Runoff drains through curb cuts or wheel stops into the planted area where it is further filtered and absorbed by vegetation. Bioswales may not be able to completely convey runoff during large storm events; therefore, underdrains with overflow drains may be incorporated into the design to convey stormwater to the sites detention areas. Bioswales are excavated to a minimum depth of 1-3 ft. A gravel layer wrapped in a non-woven geotextile provides temporary stormwater storage, which will percolate into the subsoil and/or exit via an underdrain. A loamy sand planting medium consisting of: 50% sand, 30% planting soil with minimal clay content, and 20% shredded

Depressed Parking Island Bioswale (Montcopa, PA, Planning by Design)

hardwood mulch is then placed over the gravel layer to the appropriate grade. A native herbaceous swale seed mix is planted within the bioswale to further enhance pollutant removal. Trees and shrubs may also be planted in bioswales to cool the parking lot and provide screening.

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3.2.2.3
INFILTRATION SYSTEMS

Center for Watershed Protection

Definition:

An excavated area including: on-lot infiltration practices, infiltration trenches and infiltration basins filled with coarse granular material in which stormwater runoff is collected for temporary storage and infiltration.

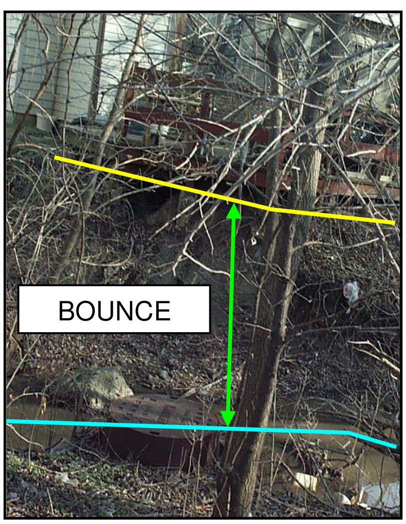
Purpose:

The primary purpose of an infiltration system is to mitigate the effects of urbanization on the natural water balance by allowing water that would normally become surface runoff to infiltrate and become a resource by recharging groundwater and providing baseflow in streams. Additionally, infiltration systems reduce the peak runoff volume and peak discharge of rain events less than or equal to the design event by temporarily storing runoff over a period of days while the water infiltrates into the surrounding soil. Infiltration systems can also reduce the amount of waterborne pollutants that would otherwise reach the receiving waters (i.e. creeks, streams, rivers, etc.). On-lot infiltration systems are typically designed for use on smaller individual lots. Infiltration trenches and basins are typically designed for use on multiple lots and require pretreatment mechanisms such as grit chambers, swales with check dams, filter strips or a sedimentation basin (See photo below).

Basic sedimentation basin Penn State

Groundwater Recharge and Stream Base Flow:

Infiltration systems can provide benefits for groundwater recharge and stream base flow. Infiltration facilities impound water that would normally be surface runoff and allow the water to infiltrate the soil, thus improving the natural water balance. By allowing surface water to percolate into the soil and travel laterally through the soil, infiltration systems filter out many pollutants before they reach our waterways. These systems also benefit riparian ecosystems by providing more consistent flows. Without groundwater recharge, waterways tend to have peak flow elevations that are higher in a shorter period of time. This condition is sometimes referred to as "bounce". Bounce contributes to stream bank erosion, damage to property, and is detrimental to plants and animals that make up a riparian ecosystem (See photo below provided by DPC).



DuPage County

Runoff Reduction

Infiltration systems provide both runoff rate and volume control. Infiltration reduces runoff rate by increasing the time it takes for runoff to reach stormwater management facilities and drainage infrastructure such as ditches, streams, lakes, and wetlands. Deep rooted vegetation aids the infiltration process by slowing stormwater flows and softening soils to allow water to percolate more efficiently and slows soil erosion in the bottom of the facility.

Runoff Pollutant Reduction:

The quality of the runoff is improved by the cleansing capabilities of the filter media, the native soil and surrounding vegetation. Infiltration systems can be very effective at removing fine sediment, nutrients, bacteria, and organic materials. However, infiltration systems may be inappropriate for industrial and commercial sites producing a significant concentration of soluble pollutants due to the potential for groundwater contamination even when a pretreatment system is used.

Site Considerations:

It is very important to consider site characteristics when developing a design. Infiltration systems that are designed, installed, or maintained improperly can have high failure rates.

- Infiltration systems are better suited to sites with permeable soils, gentle slopes, relatively deep groundwater and bedrock levels, and small contributing watershed areas.
- Infiltration systems should be preceded by some sort of pretreatment (i.e., grit chambers, swales with check dams, sedimentation basins) to lower the concentrations of sediment and suspended solids before the runoff reaches the infiltration facility, thus

reducing the potential of clogging in the infiltration system.

- Infiltration systems are typically designed to treat the first flush, they do not have the capacity to detain storms larger than the one- or two-year event. To determine the well volume required to treat the first flush, multiply the new impervious area by the depth of the run-off and divide by the void ratio.

> S=1000/CN-10 ➔ S(exist)=3.51 S(prop)=0.204
>
> Where $Q=(P-0.2S)^2/(P+0.8S)$
>
> 2yr, 24hr = 3.04in ➔ Q(exist) = 0.94in Q(prop) = 2.81in ➔ Difference = 1.87in
>
> =((tributary impervious area in sf.) x (1.87 in)) / ((12in/ft) x (0.40))
>
> ➔ Volume required by a drywell to treat the water quality storm =tributary impervious area in sf. X 0.39 ft.

- A flow splitter may be used to divert excess runoff to a separate detention facility for events larger than the design event.
- To avoid groundwater contamination and allow the facility to function hydraulically, the bottom of the infiltration basin should be a minimum of three feet above the seasonally high groundwater table. For the same reasons, the bottom of the infiltration facility should be a minimum of three feet above bedrock.
- The most important factor to consider when evaluating a site in DuPage County for an infiltration system is the infiltration rate of the surrounding soils.
  - The infiltration rate of the soils should allow the pond to drain within 72 hours. This translates to an infiltration rate of 0.5 inches per hour (1.3 centimeters per hour) or greater.
  - SCS Type A and B soils meet this infiltration rate, but site-specific soil testing should be performed, especially in DuPage County where so many of the soils are SCS Type C and have high clay content that will impede infiltration rates.
  - Only about 18% of the soils in DuPage County, according to the SCS Soil Survey of DuPage County, can support an infiltration system.
  - Soils with more than 40% clay content are subject to frost heave.
- Due to the predominance of poorly draining soils in DuPage County, many areas of the County experience a seasonal high groundwater table. Elevated groundwater elevations are often encountered shortly before and into the first few months of the growing season. Care should be taken when locating infiltration systems to account for a possible seasonal high groundwater elevation through monitoring of groundwater elevations. Infiltration systems should be elevated so that the bottom of the system is at least three feet above the seasonal high groundwater elevation.
- Freezing can cause failure of the infiltration system during the winter months.
  - The surface of the facility must be kept free of compacted snow and ice in order to prevent untreated surface water from sheeting over the facility.
  - As the surrounding soils freeze, infiltration rates are reduced. In order to combat the effects of the reduced infiltration during the

winter, part of the facility should be constructed below the frost line, as long as it remains three feet above the groundwater table and bedrock. The facility can be oversized to account for the seasonal reduction in infiltration rate.

- An underdrain system may also be considered to achieve ideal operation during the winter months.

Maintenance Procedures and Costs:

Construction techniques have a significant impact on the functionality of the infiltration facility. The infiltration facility should be constructed at the end of the development construction schedule. Do not allow heavy equipment to travel across the area being considered for the infiltration system. The weight will compact the soils and hinder the infiltration capabilities of the soil. During construction, proper sediment and erosion control techniques must be observed to prevent sediment from entering the facility. Maintenance activities must include frequent inspections at the beginning of the facility's operation. These inspections should note sediment accumulation, debris accumulation, and clogging of inlet and outlet pipes.

Infiltration systems play a critical role in the natural water balance by allowing surface water to infiltrate and become a source for recharging groundwater and maintain a base flow is streams. Maintenance procedures such as, invasive species and weed control on or within rock surface infiltration systems can cause potential groundwater contamination through use of various herbicides. Therefore it is vital that the release of chemical constituents be kept to a minimum to avoid impacts to water quality. Herbicides should be applied in the most efficient way as possible. These include the use of "spot treatments," which involve the application of herbicide to individual exotic plants or weeds via a backpack sprayer, hose or wick applicator. Additionally, herbicide application should be applied by a licensed applicator and recommended doses strictly adhered to.

Costs for installing and maintaining infiltration practices change often; therefore, please see Table 2-4 for a comparative analysis of different BMPs.

Soak Away Pit Details:

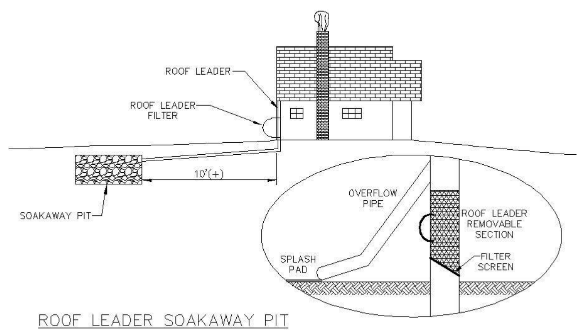


Figure 3-8 Roof Leader Discharge to Soakaway Pit

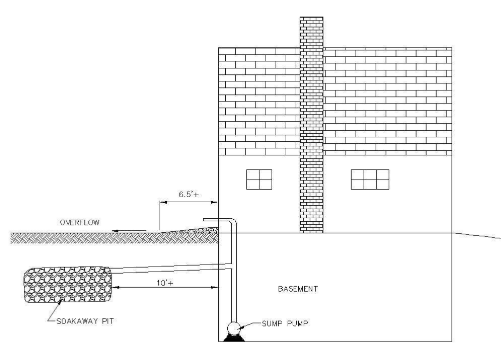


Figure 3-9 Sump Pump Drainage to Soakaway Pit Detail

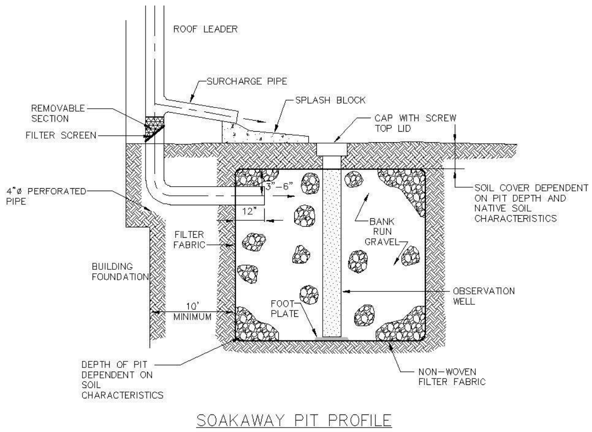


Figure 3-10 Soakaway Pit Profile

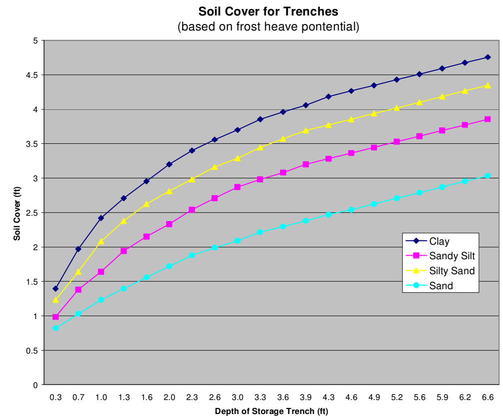


Figure 3-11 Recommended Soil Cover (Figures 3-8 – 3-11 are Adapted from Ontario Ministry of Environment, 1999)

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3.2.2.4
PERMEABLE PAVERS

Illinois Urban Manual

Definition:

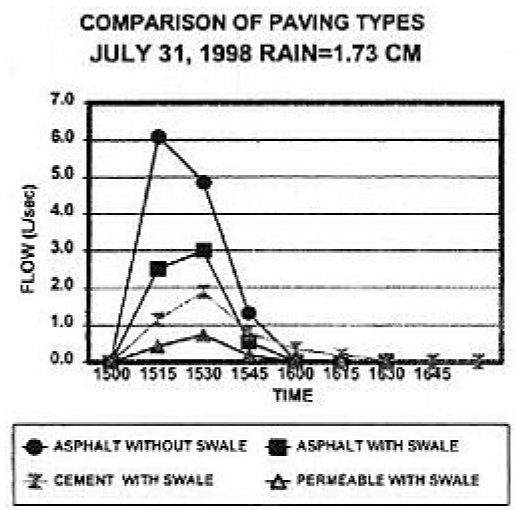
Permeable paver systems are strong structural materials containing regularly interspersed void areas, which are filled with pervious materials such as gravel or turf grass.

Purpose:

The primary purpose of utilizing these alternative paving materials is to infiltrate rainwater, reduce runoff, eliminate problems with standing water, provide opportunities for groundwater recharge, decrease downstream flooding to control the erosion of stream banks, facilitate pollutant removal, and provide for a more aesthetically pleasing site. These semi-permeable surfaces can replace concrete and asphalt surfaces on driveways, parking lots, walkways and private roads. There is also potential for use in public streets for low-use and low-speed applications. Additionally, underground stormwater sewers can be replaced by the base rock section of paver systems. Permeable pavers can work alone or in conjunction with other BMPs in a treatment train.

Runoff Reduction:

Permeable paver systems provide both runoff rate and volume control. Runoff rate is reduced by increasing the time it takes for runoff to reach stormwater management facilities and drainage infrastructure such as ditches, streams, lakes, and wetlands. Runoff volume is reduced by providing opportunities for runoff to infiltrate the permeable soil beneath the permeable paver system. In the University of Guelph experiments, field sites with permeable interlocking concrete pavers, when used in conjunction with a swale, demonstrated a 90% reduction in runoff volume. However, during high intensity rainstorms or when soil is already saturated due to previous events, runoff volume is not reduced as substantially (see following figures). Therefore, as permeable paver systems are more effective in smaller storm events, stormwater management must still be provided in accordance with the DCSFPO.



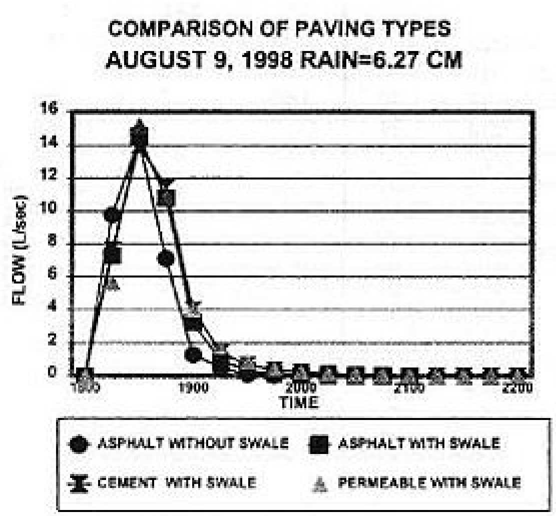


Figure 3-12 Southwest Florida Water Management District, 2001

Runoff Pollutant Reduction:

The quality of the runoff is also improved by the cleansing capabilities of the porous material and the underlying native soil. Pervious paver systems can be very effective at removing total suspended solids, nitrite, nitrate, phosphate, phosphorus, metals, BOD, and ammonium. Additionally, surface runoff temperatures may be decreased by 2 to 4 degrees Celsius as compared to typical asphalt paved areas. Pervious paver system studies have shown a removal efficiency of up to 91% for total suspended solids, and 75 to 92% for metals (copper, iron, manganese, and zinc). However, permeable paver systems may be inappropriate for industrial and commercial sites producing a significant concentration of soluble pollutants due to the potential for groundwater contamination.

Site Considerations:

Pervious paver systems can provide temporary stormwater storage and water quality improvement under light to moderate runoff conditions. As such, permeable pavers are best suited for use in minimally populated residential, industrial and commercial areas for driveways, parking lots, walkways and private roads. There is also potential for use in public streets for low-use and low-speed applications.

Typical applications include:

- Vehicular Access
  - ❖ Residential driveways
  - ❖ Service driveways
  - ❖ Roadway shoulders, crossovers, and medians
  - ❖ Fire lanes and utility access
- Parking
  - ❖ Church
  - ❖ Employee
  - ❖ Overflow
  - ❖ Event
  - ❖ Guest
- Slope Stabilization, Detention Basin Overflows, and Erosion Control
- Trails
  - ❖ Bicycle
- Golf Courses
  - ❖ Cart Paths
  - ❖ Cart Parking
- Pedestrian Access
  - ❖ Approaches to monuments, statues, and fountains
  - ❖ Areas for outdoor special events
  - ❖ Picnic areas and highway waysides
  - ❖ Pathways and trails

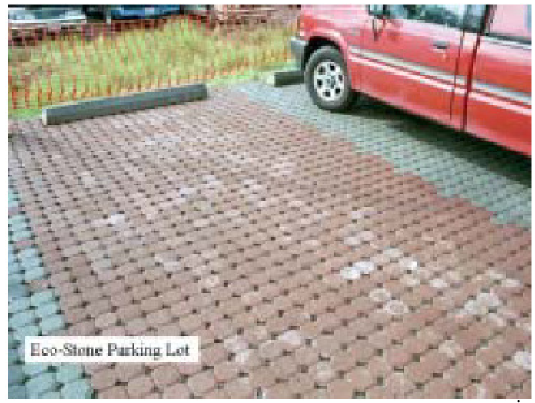
Permeable pavers used for driveway (The Journal for Surface Water Quality Professionals, Stormwater Features 2002)

There are several key elements to consider when designing a permeable paver system, including: material, hydraulic design (the ability for water to pass through the top layers of pavement and the ability to temporarily store water in the bottom layer) and structural design (total traffic, in-situ soil strength, environmental elements and actual layer design).

<u>Materials:</u>
Pervious paver systems can be constructed with stone or soil and grass filled interlocking concrete blocks or stone or soil and grass filled plastic cell networks.

Concrete pervious paving methods are cast-in-place or pre-cast modular units.

- **Cast-in-place paver systems**- are monolithic and are made with reusable forms to create the voids needed for gravel or soil medium for planting grass. This system is stronger and can prevent settlement when it is reinforced with welded wire mesh.
- **Pre-cast paver systems-** are modular and are laid out individually in a pattern perpendicular to the flow of traffic. This method is less labor-intensive than that of cast-in-place systems.



Pervious concrete block (UniEco-Stone[i]) parking lot at Multnomah Arts Center (SW 31^{st} & Capitol Hwy)

Plastic pavers have less intrinsic strength than concrete pavers. Plastic pervious paving systems are also mostly contained of 50 to 100% post-consumer recycled materials and are either flexible or rigid modular units.

- **Flexible plastic paver systems-** come in long rolls which can be laid out quickly and can be easily installed over irregular surfaces.
- **Rigid plastic paver systems-** are modular and are laid out individually in a pattern perpendicular to the flow of traffic.

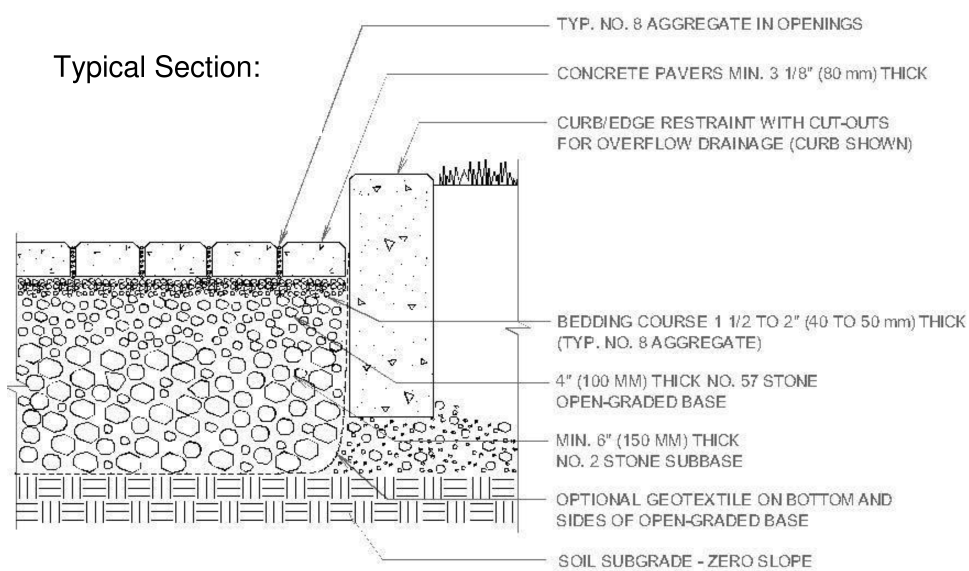
Bayview Corner, Whidbey Island. Left photo: during construction. Right photo: after construction.

- Grass-filled pavers are useful in overflow parking areas, emergency access lanes, golf course cart paths, and special event parking lots, where a more natural look is desired.
- Grass-filled concrete or plastic pavers require more labor than stone-filled pavers as preparation of soil, sodding (for plastic systems) or seeding (for concrete systems), and irrigation is needed until the grass is established. Grass-filled systems require a 1 to 2 month time period allowing the root system to fully develop prior to allowing traffic through the area. There are numerous manufacturers of both concrete and plastic pavers.

<u>Typical Cross-Section:</u>

- A typical permeable paver cross section consists of four layers: a concrete or plastic paver filled with gravel or topsoil and grass, a 2” thick support layer of sand (preferably granite shavings), a geotextile filter fabric which allows water to infiltrate but restricts the movement of other particles into the bottom layer, and a gravel base sized to support the weight of traffic and temporarily store stormwater runoff.
- There may also be a perforated pipe under drain system where native soils do not infiltrate well or where infiltration is not desired.
- A geotextile filter fabric is also recommended between the gravel base layer and soil subgrade.

See the figure below for a typical cross section:



NOTES:
1. 2 3/8" (60 MM) THICK PAVERS MAY BE USED IN PEDESTRIAN APPLICATIONS.
2. NO. 2 STONE SUBBASE THICKNESS VARIES WITH DESIGN.
CONSULT ICPI PERMEABLE INTERLOCKING CONCRETE PAVEMENT MANUAL.

Figure 3-13 Typical Permeable Paver Cross Section
(Interlocking Concrete Pavement Institute ICPI-68 Permeable pavers - full exfiltration)

Hydraulic Design:

- Key elements in the hydraulic design of permeable pavers are: The ability of water to pass through the top layers (concrete or plastic pavers, sand, and permeable blanket) of pavement easily and the ability to store water in the bottom gravel layer.
- Runoff from permeable pavers is usually generated by water not being able to infiltrate the surface layer quickly enough.
- The gravel layer below will temporarily store runoff while it slowly infiltrates into the underlying soil.
- The earth below the gravel layer should be flat to discourage water from ponding at the bottom of slopes. The slope should not exceed 5%.
- The degree of storm which can overwhelm the infiltration capacity of the surface layer and the amount of storage needed in the gravel layer can be calculated by using the steps described in the Hydraulic Design for Permeable Pavement Worksheet in Appendix 4.6.

It is important to remember that each paver system has its own set of specifications. The manufacturer should be able to provide assistance in determining the above.

Structural Design:

There are four key elements needed when designing the structural aspects of permeable pavers. These elements include: total traffic, in-situ soil strength, environmental elements and actual layer design.

- **Total Traffic-** involves estimating the vehicle weight, the number of vehicles passes, converting vehicle weight to established factor, deciding design life, and calculating the total expected load.
- **Soil strength-** is determined by the soil type, base strength, and converting to a soil support value.
- **Environmental factors-** are the amount and frequency of rainfall and the ability of the underlying soil to infiltrate water.
- **Actual layer design-** is determined by using the above elements.
- These elements can be determined/calculated by using the steps described in the Structural Design for Permeable Pavement Worksheet in Appendix 4.6.

The manufacturer should also be able to provide assistance in determining the above.

Freeze-Thaw Concerns:

There are some concerns with regard to winter weather when deciding to use permeable pavers. Some references have indicated that plows cannot be used; however, if the plow is ½” to 1” off the pavers they still can be used during winter months. Manufacturers of interlocking pavers form the top edges of the blocks to minimize chipping due to plowing. However manufacturers still recommend the use of skids along the edges of plow blades. Permeable pavers also experience fewer effects from frost heave than impermeable pavement (Backstrom, 1987, 1999). Air spaces in the gravel layer delay the ground from freezing and help melt frost; therefore, the pavers are more resistant to freezing and thaw quickly after being frozen. When snow melts, water usually ponds on typical impermeable pavement surfaces and poses a risk for refreezing forming a safety hazard. Permeable pavers allow the periodic melt to infiltrate before refreezing occurs. However, some deicing chemicals may be required depending on the proposed use of the area. The most common deicing chemical used is salt, either in the form of sodium chloride or calcium chloride. The use of deicers containing ammonium nitrate and ammonium sulfate shall be strictly avoided as the rapidly attack and disintegrate concrete. If only a small amount of salt is applied, this will tend to initiate a number of freeze-thaw cycles, rather than just the one if an adequate amount is used. If salt is used on permeable pavers, it should be used sparingly, as it may pose a potential pollution problem. Sand should also not be used as it often fills the voids causing the system to clog.

Maintenance:

Permeable pavers can last up to 20 years, and have lasted as long or longer than impermeable asphalt (Gutowski, 2003) (Holland, 2003). Maintenance of pavers is minimal but necessary to ensure long term viability. Maintenance procedures include: mowing and watering grass pavers, sweeping organic materials off of gravel-filled pavers, conventional street sweeping with vacuums, brushes, and water to clear out voids (aggregate fill may be needed following each cleaning to refill the voids). Some sections can settle over time due to poor compaction, subsoils, or construction techniques. These areas can easily be taken up and replaced and do not require cutting to do so. A cost benefit analysis by Lake County Forest Preserve for building and maintaining permeable paver systems as opposed to asphalt has been provided in Appendix 4.7.

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Southwest Florida Water Management District, 2001: *Florida Aquarium Parking Lot - A Treatment Train Approach to Stormwater Management.* Final Report for FDEP Contract No. WM 662, Brooksville, Florida, 220 pp.

Stormwater Managers Resource Center, Better Site Design Fact Sheet: Alternative Pavers Accessible at http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool4_Site_Design/AlternativePavers.htm

Structural Design of Permeable Pavements Worksheet. Accessible at http://www.bae.ncsu.edu/cont_ed/pavement/lectures/strucworksheet.pdf

Sustainable Infrastructure Alternative Paving Materials Subcommittee Report, October 3, 2003, 8-11pp. Accessible at http://www.portlandonline.com/shared/cfm/image.cfm?id=41626

[i] This is a photo of one of many permeable paver systems that may be acceptable.

3.2.2.5
MANUFACTURED BMPS

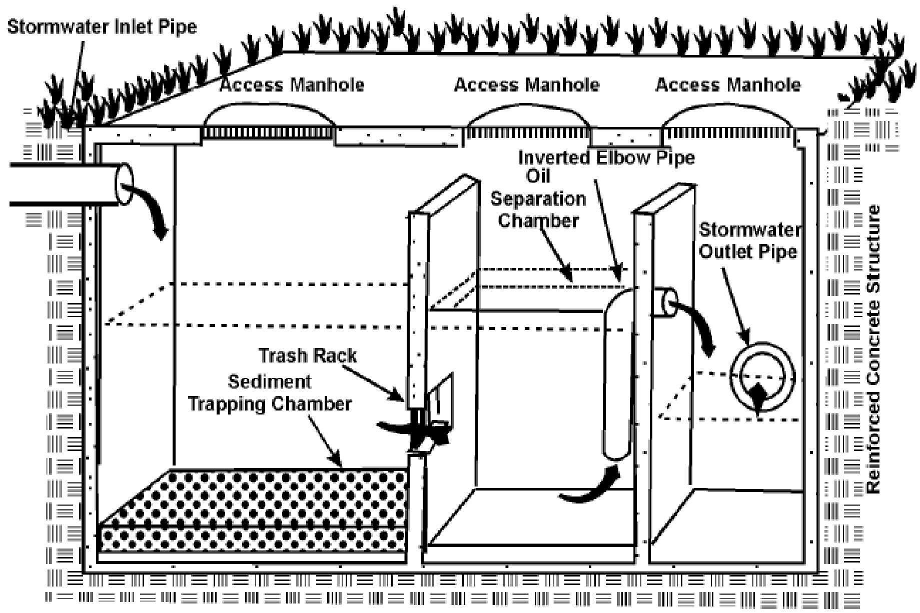

Figure 3-14 Typical Oil Grit Separator (Berg 1991)

The above illustration is a generic diagram of a manufactured BMP. Manufactured BMPs have come a long way since their inception. There are numerous manufactured BMPs on the market ranging from oil and grit separators to sand or biomass filters. Depending on the design parameters of the system, these can capture small to large amounts of pollutants. They are capable of trapping debris, oil, grease, sediment, and other floatables that would otherwise be discharged to water resources.

Types of Manufactured BMPs:

Manufactured BMPs for the purposes of this manual include, but are not limited to, separating and settling devices.

Separating/Settling Devices:
These are flow-through devices, also known as hydrodynamic separators, which rely on gravity to capture both floating and settleable pollutants. They are currently the most widely utilized class of manufactured device. They utilize laminar sedimentation or vortex separation to remove settling solids and floatation to remove non-settling solids. Laminar sedimentation is the settling of particles as water passes through closely separated plates, the effect of which is to

create non-turbulent flow. Vortex separation is the settling of particles via a circular motion strong enough to separate the removal of solids through centrifugal forces. Floatation is a process in which gravity removes particles with densities less than that of water. (Minton, 2005)

These devices are most effective when they are designed to target and treat runoff from small, frequent rain events that produce the vast majority of runoff volume. They are susceptible to hydraulic loading. As the flow rate to the device increases, removal of pollutants generally decreases. If too much flow is routed through the device, previously captured pollutants may be re-suspended, resulting in marginal or negative environmental benefit. Therefore, it is important that these devices be designed to treat a specific storm runoff volume. If a manufactured device has not been verified or certified for scour prevention, the unit should be installed in an off-line configuration to prevent scour and re-suspension.

Many of devices target primarily trash and sand sized particles. However, many pollutants attach to finer particles, such as silts and clays, and colloids, due to their larger surface area. These finer particles contribute to much of the sediment in DuPage County. Please see the particle size distribution table below.

Table 3-5 Engineers Classification of inorganic solids

Size Range	Classification
D<0.5 micron	Colloids
0.5<D<5 micron	Clay
5<D<50 micron	Silt
50<D<2mm	Sand
2mm<D	Gravel

(Minton, 2005)

Therefore, it is important that these devices be designed to treat a specific particle size. In most instances the OK-110 Particle Size Distribution should be used. However, the default distribution may be altered to accommodate for site specific needs, such as gravel storage areas and areas where the native soil may contribute to loading.

Dissolved pollutants and colloids, sediments so small at the point of becoming dissolved (D< 0.45 microns), will not settle by gravity and therefore cannot effectively be treated by these devices. Also, sizing a separating/ settling device to treat 100% of the runoff volume from a large "design storm" event often results in a dramatic increase in BMP unit size and cost. As such, these devices should be used with other BMPs in a treatment train.

Design Parameters:

The following is a list of stormwater, particle size, and product design requirements. It is important to note that the technology of these BMPs is constantly changing and specifications and individual pollutant performance criteria can be obtained from the manufacturers of these systems. The applicability and specifications of each device will be reviewed on a case by case basis.

<u>Stormwater Treatment Volume</u>:

- Systems should be designed to effectively treat the water quality storm (approximately 3.04 inches in a 24 hour time period in Northeastern Illinois) at a minimum. Effective treatment is defined as 80% TSS removal from the design storm, with the TSS being defined as the Ok-110 PSD.

- Effective treatment also constitutes removal of a minimum 80% of the free floatable hydrocarbons in the runoff to the device before bypass.
- A bypass provision is required to divert the high-velocity, turbulent flows of large storm events, as these intense flows exceed the scour velocity of the smallest particles being targeted for removal. The bypass provision protects previously captured contaminants from being re-suspended and discharged from the system under high flow conditions.
- An alternate sizing method such as US EPA SWMM could be utilized based on local historical rainfall utilizing a continuous simulation model. These sizing methods are acceptable as long as they are consistent with removing 80% of the annual TSS, with the TSS being defined as the Ok-110 PSD. In certain situations this sizing method may be required.
- Sizing should account for site drainage area, percent imperviousness, TSS loading, and Ok-110 PSD or particle size distribution typical of that within the runoff from the site.
- Sizing methodologies shall provide calculations substantiating TSS removal efficiencies and demonstrate correlation to field monitoring results using both particle size distribution and TSS removal.

<u>Retention of Accumulated Pollutants during Large Rain Events</u>:
The device must retain previously accumulated pollutants (sediment and hydrocarbons) during high flow conditions. Previously accumulated pollutants must not be re-suspended (scoured) and discharged from the device.

Certified laboratory or field monitoring results must demonstrate that the system does not scour when the flow rate is 200+% of the designed operating rate and the sediment depth in the treatment chamber is 50% of the rated sediment capacity. Particle size distribution for the sediment load shall conform to the Ok-110 PSD.

<u>Maintenance</u>:

- Maintenance should consist of inspecting and cleaning the devices as required during construction if the unit is in service. These devices can be subjected to very heavy sediment loads during construction. There should be a post construction inspection and cleaning if required as per the manufacturer's recommendations. The inspection frequency following commissioning should be no more than annually with cleanings conducted as required based on the inspection results.
- The inspector should be qualified and the cleaning company should employ a vacuum truck. The inspector and the cleaning company are often two separate entities
- The pollutants should be disposed of in accordance with the local and state regulations.
- An inspection report should be submitted to the County on an annual basis.
- Maintenance personnel shall contact the owner immediately if the device is damaged or not functioning to the extent it was design for. It is the owner's responsibility to repair or

replace the device if it is damaged or failing.

References:

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3.2.3 Stormwater Detention BMPs

Stormwater detention areas are constructed depressions where discharge is restricted in order to store stormwater and gradually release it downstream. Stormwater detention is required by the DuPage County Countywide Stormwater and Floodplain Ordinance and all communities located within the County. Stormwater detention is the most common means for treating runoff volume and pollutants. Stormwater detention can provide 0%-100% pollutant removal for various constituents. There are many types of detention designs, each with advantages and disadvantages. A thorough site evaluation is needed to determine the appropriate design and location for the proposed detention.

A word about *extended detention*. Extended detention is a term often used in BMP references and refers to extending the residence time stormwater runoff remains within a stormwater management facility. With extended detention, the stormwater management facilities pollutant removal abilities are increased with the increase in residence times. Common techniques that provide extended detention included utilizing two stage outlets and/or permanent pools located below outlet elevations to allow for infiltration. Under certain site conditions, similar water quality benefits may be realized through judicious application of the existing single stage release rate found in the DCSFPO, thereby eliminating the need for more complicated restrictor/pond designs. Section 15-114.2 of the DCSFPO requires that detention facilities not exceed 0.1 cfs/acre in a 100 year storm event. This release rate and associated design criteria of Section 15-114 is considerably stricter than typical requirements found in most areas of the nation. In particular, the DCSFPO does not provide for a minimum restrictor size. As a result, many detention facilities are designed with restricted outlets of such small size that special protection from debris blockage is needed. When combined with the other requirements of Section 15-114 providing for a restrictive release rate over a full range of events, a significant water quality benefit can be realized. However, it is important to note that this benefit is quickly lost if the drainage area of the facility includes significant upstream tributary area in its design as the restrictor size must be increased to pass these off-site flows. Such ponds may require a two stage outlet or additional "dead" storage volumes beyond the detention design volume to extend the residence time if additional BMPs are not incorporated into the pollution control plan.

Runoff rate and volume reduction:

In DuPage County, stormwater detention must control runoff rates for small storms in addition to the 100-year storm. This helps to manage and mitigate the effects of urbanization on stormwater throughout the County reducing the potential of damage to public health, safety, life, and property caused by flooding. Providing stormwater detention minimizes increases in downstream flooding and controls high flow velocities which may cause bank erosion in downstream channels.

Runoff Pollution Reduction:

Stormwater detention basins can remove pollutants via a variety of physical, chemical, and biological processes. Detention basins treat runoff pollution by detaining runoff for a period of time (residence time), which allows some pollutants to settle out. Pollutant removal within basins can also occur via infiltration, biologic uptake and transformation by aquatic organisms and wetland vegetation. Contaminant removal mechanisms that may be present in detention basins are outlined in the Table 3-6, below:

Table 3-6 Contaminant Removal Mechanisms

Mechanism	Description	Contaminant affected	Enhancement techniques
Absorption	Assimilation of gas, liquid, or dissolved substance into another substance.	• Phosphorus • Synthetic organics • Oil	• Long residence times • Low flow velocities
Adsorption	Adhesion of dissolved pollutants to suspended solids, sediments or vegetation. (Electrical attraction between positively charged pollutant particles and negatively charged pollutant particles such as sediments).	• Phosphorus • Heavy metals • Synthetic organics	• Shallow water depth • Long residence times • Sheet flow • Al and Fe soils (remove P) • Organic soils • Circumneutral pH
Filtration	Physical entrapment of suspended particles by vegetation, biota and sediments	• Organic Matter • Phosphorus • Nitrogen • Pathogens • Heavy metals • Suspended solids • Synthetic organics	• Sheet flow • Low flow velocities • Dense vegetation
Microbial metabolism	Desirable modification of pollutants and other elements in water that form insoluble substances that settle	• Heavy metals • Phosphorus	• Scattered vegetation • Permanent pool of water • High plant and soil surface area
Precipitation	Chemical reaction between dissolved pollutants and other elements in water that form insoluble substances that settle	• Heavy metals • Phosphorus	• Low flow velocities • Long residence times • High alkalinity
Sedimentation	Physical settling of particles and attached pollutants	• Organic Matter • Phosphorus • Nitrogen • Pathogens • Heavy metals • Suspended solids • Synthetic organics	• Low flow velocities • Long residence times • Sheet flow • Dense vegetation
Uptake by vegetation	Respirational uptake through plant tissue and conversion to plant biomass	• Nitrogen • Phosphorus • Heavy metals	• Dense vegetation (large surface area)
Vaporization	Evaporation into the air	• Oils • Chlorinated hydrocarbons • Synthetic organics	• High temperature • Air movement (wind) • Turbulence • Reduced surface films

(adapted from Watson tal., 1989 and Horner, 1992)

Total suspended sediments and heavy metal removal rates in natural detention basin designs range from 60% to 90%; while, dissolved pollutants and organic matter can be reduced by 40% to 80%. Naturalized detention basins also provide wildlife habitat for aquatic and terrestrial animals. The lack of a permanent pool or wetland vegetation reduces the effectiveness of pollutant removal. Pollutant removal rates in ponds without permanent pools or wetland vegetation range from 30% to 70%; while, dissolved pollutants and organic matter can be reduced by 15% to 70%. Native wetland plants also aid in the establishment of organic soil. Studies indicate that the supply of organic carbon in soils provide even greater nutrient removal than plant uptake alone. Vegetation provides a necessary litter layer of decaying plants and aerobic zone for microbial activity that promotes the detrification process which aids in the pollutant removal process.

Design Considerations:

Information can be found in this section on the application and design of the following BMPs:

- Dry Detention
- Wet Detention
- Wet/Wetland Detention
- Constructed Wetland Detention
- Manufactured- Underground
- Detention Retro-fit

Prior to discussing the above detention options, it is important to define several key terms pertaining to detention:

Water Quality Storm: The water quality event recommendation is the 2-year, 24-hour storm event (3.04 inches in a 24 hour duration in Northeastern Illinois).

Low Frequency: A type of pond design where the water quality storm volume is diverted to a treatment pond by a control structure. When the low frequency pond becomes full, the remaining runoff bypasses the pond and flows directly to the main stormwater storage area. This approach allows for the segregation of the “first flush” of runoff, which may contain the majority of pollutants. NOTE: Manuals in other areas of the U.S. may define this as off-line; however, this term has been re-defined to avoid confusion with the DuPage County concept of off-line detention.

Full Frequency: A type of design in which all of the runoff from a storm is routed through a pond. This method may have lower pollutant removal efficiency than low frequency ponds as the most polluted volume is mixed with the entire storm volume and leaves the pond as dilute polluted water.

Detention: The collection and temporary storage of stormwater for a period of time, in such a manner as to provide for treatment through primarily physical, biological, and to a much lesser degree, chemical processes with subsequent gradual release of stormwater downstream.

Retention: On-site storage of stormwater with subsequent disposal by infiltration into the ground or evaporation in such a manner as to prevent direct discharge of stormwater runoff into receiving waters.

Hydraulic Residence Time:
The length of time that runoff remains in the basin (i.e., the time it

takes for the volume in a basin to subside to the normal water level or bottom of the basin). This recovery may be accomplished by either infiltration or controlled release through an outfall structure.

Guide for Best Management Practice (BMP) Selection in Urban Developed Areas, 2001

During initial design of the various stormwater detention BMPs, several key elements should be addresses. Firstly, design consideration should include eliminating "dead zones" or areas of minimal water circulation. By doing this, you greatly reduce the risk of algae buildup and mosquito breeding. Secondly, design consideration should include an analysis of water surface elevation over time for the 1, 2, 5, 10, and 100-year, 24-hour storm events. This data is fundamental in determining the location of plant zones and species selection, as many plants are not likely to survive under high levels of water fluctuation and long drawdown periods. Recommended plant species for stormwater detention basins can be found in Appendix 4.3.

Weather Considerations:

Many types of BMPs can be negatively impacted by winter weather. DuPage County is noted by the EPA as an area where average winter temperatures are of concern.

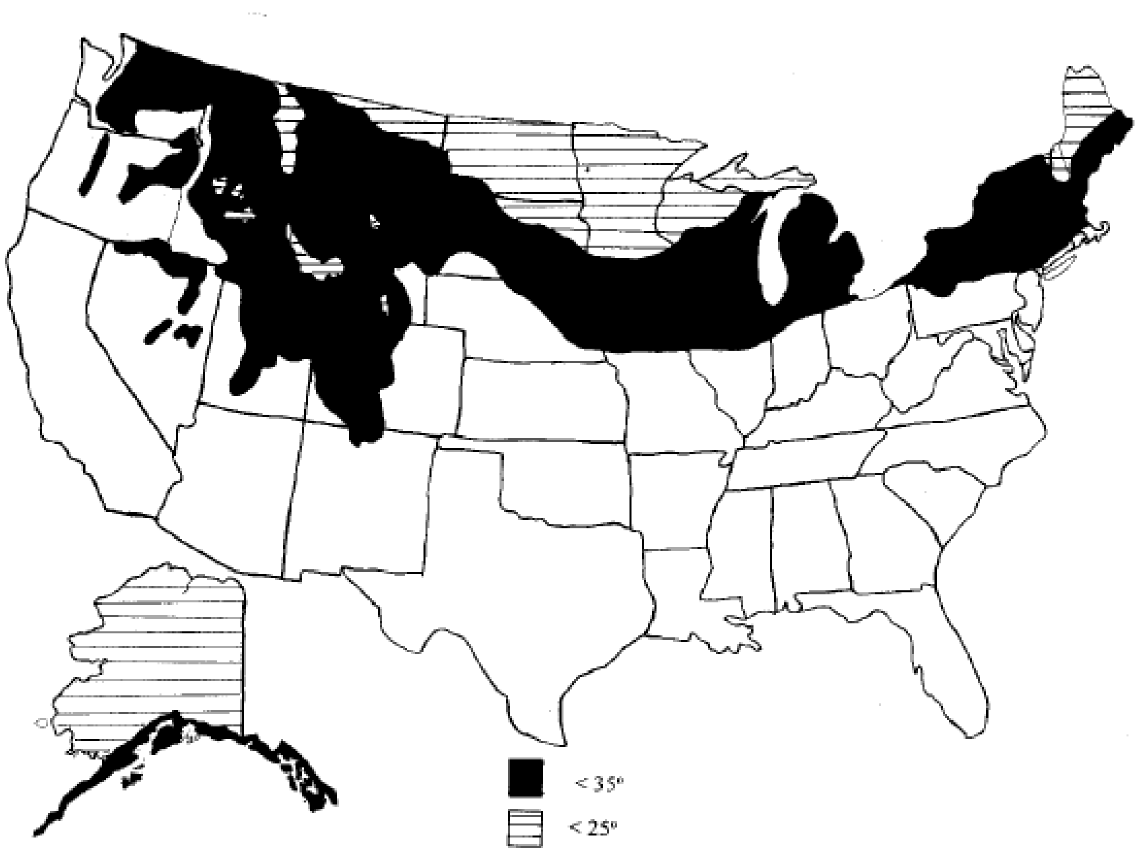

Figure 3-15 Normal Daily Maximum Temperature (°F) For January (U.S. Doc, 1975)

Specifically, BMPs that utilize soil infiltration, vegetation, and stilling basins can experience greatly reduced efficiency in winter weather. Frozen soils greatly reduce or eliminate the ability to infiltrate stormwater. In addition, pollutants can “skate” across frozen dry bottom detention ponds or across ice resulting in inadequate treatment time as stormwater quickly exits the facility. When designing detention facilities for maximum water quality benefit, consideration must be given in the design of inlets, outlets, restrictors, and stormwater runoff travel time for winter weather. Also, use of the “treatment train” concept can help minimize winter weather concerns.

3.2.3.1
DRY DETENTION BASINS

Dry Detention with Recreation Fields
(Pennsylvania Stormwater Management Manual)

Definition:

Dry detention basins are full frequency ponds that completely drain between storm events and are typically vegetated with turf grass along the bottom and side slopes of the pond.

Purpose:

- While dry detention basins may be used for active recreation such as ball fields, they are generally not recommended as the release rate required by the County often causes the duration of ponding to be too lengthy to maintain turf grass. Pollutant removal in dry bottom detention basins vegetated with turf grass is also very poor. Dry bottom basins may be vegetated with native species that are more tolerant of lengthy inundation and provide enhanced pollutant removal rates. A combination of turf and native vegetation can be utilized where active recreational uses are needed by vegetating the upper level of the basin that is not subject to frequent

Low Water Quality Benefit Dry Pond

or lengthy inundation with turf for recreational uses and the lower level which is subject to frequent and lengthy inundation with native species that are tolerant to this condition. If other BMPs are not incorporated into the development, planting any portion of the basin within 10 ft of the High Water Level with turf may not be permitted. Minimum planting diversity standards, maintenance procedures, and performance standards should be in accordance with Appendix 4.4.

Site Considerations:

Slope, drainage area, outlet structures, low flow channels, and several design variations are discussed below:

Slope:

- The maximum side slope for a dry bottom detention basin should be no greater than a 4:1 ratio to allow for maintenance activities, side slope vegetation establishment, and to prevent slope slumping during draw down periods.
- The bottom slope should be no less than 1-2% for dry detention basins to ensure proper drainage between storm events.
- The flow path from the inlet to the outlet should be as long as possible to maximize the time the runoff is treated in the basin.
- Once Groundcover has been established periodic removal of thach should take place. This ensures that thatch buildup will not accidentally result in a loss of positive pitch.

Drainage Area & Outlet Structure:

- The Stormwater Manager's Resource Center recommends that dry detention basins should not be used on sites with less than 10 acres of drainage area.

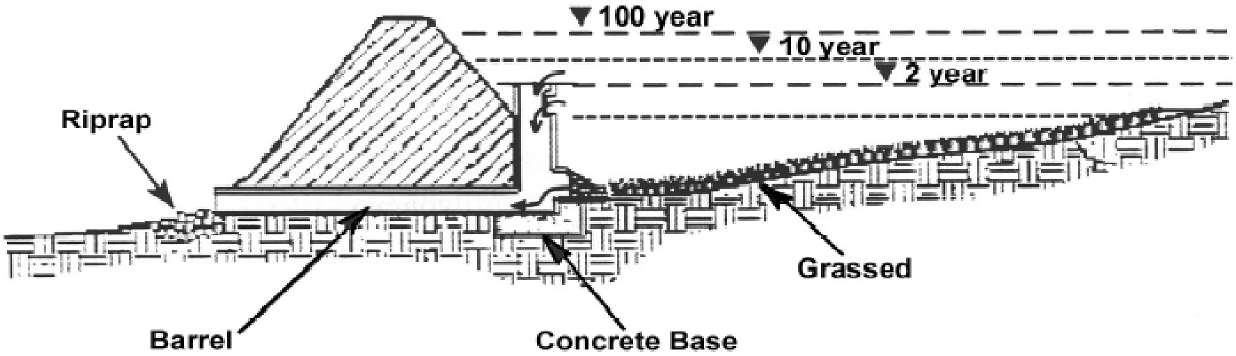

Figure 3-16 Typical Dry Detention Basin Cross Section (Minnesota Urban Small Sites BMP Manual)

- Small diameter outlet orifices may allow for longer residence times which facilitate settling of finer sediments prior to leaving the basin.
- Dry detention basins with larger drainage areas utilize a larger diameter outlet orifice allowing smaller storm "first flush" events to drain quickly lessening the opportunity for treatment of pollutants. In order to meet water

quality goals in basins with large drainage areas, extended detention, and utilizing a forebay at the inlet and a micropool at the outlet may be necessary to trap sediment and reduce re-suspension. The forebay should be a permanent pool greater than 3 ft in depth and the micropool is a shallow undrained pool located just before the outlet structure in sequence.

Cold climates similar to those found in northeastern Illinois can pose many problems when designing dry detention basins. Frozen ground throughout the tributary area to a dry basin increases impervious area. Therefore, more runoff during winter rains and snow melt will reach the basin. Runoff during the winter months may have a higher pollutant load and may contain high salt concentrations due to road de-icing. Fortunately, winter rains and snow melts are generally lesser in volume than those in other seasons and will continue to be captured in their entirety in a basin designed for the 10-year event. The use of forebays and micro pools help minimize winter weather concerns as adding these structures minimizes pollutant laden stormwater from "skating" on frozen surfaces and can trap pollutants on top of or below pond ice to allow for adequate treatment times. Note the addition of a "hood" at the outlet to prevent runoff from traveling across ice and directly into the outlet.

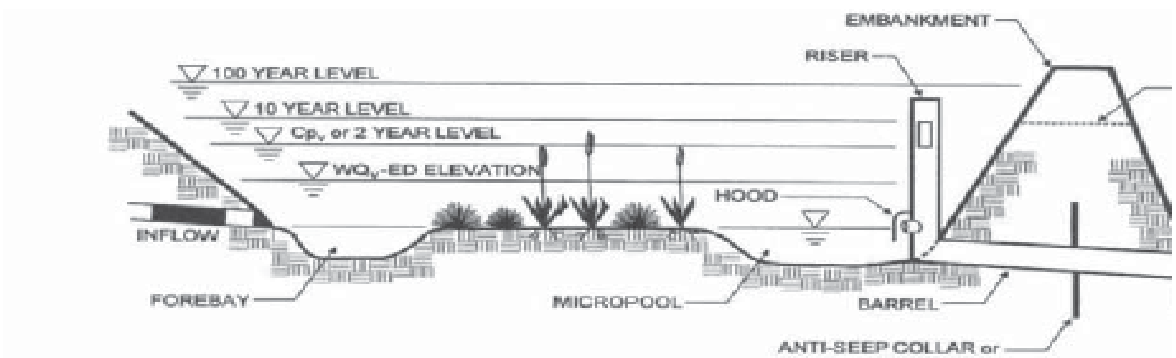

Figure 3-17 Typical Dry Extended Detention Basin Design Profile (Maryland BMP Manual, 2000)

A comparison of pollutant removal efficiencies in dry detention and extended dry detention practices is provided in Table 3-8 below.

Table 3-7 Dry Detention Pollutant Removal Efficiencies

Pollutant Constituent		Pollutant Removal Efficiencies (%)	
		Dry Detention Basins	Extended Dry Detention
Solids	TSS	47	61
Nutrients	Total Nitrogen	25	31
	Total Phosphorus	19	20
	NO_x	-6	-2
Trace Metals	Zn	26	29
	Cu	26	29

National Pollutant Removal Performance Database for Stormwater Treatment Practice's: 2nd Edition vegetation resulting in increased pollutant absorption.

- The design velocity within pervious low flow channels should be high enough to prevent sedimentation and low enough to prevent scour and erosion.
- A forebay utilized at the inlet of the dry detention basin will also prevent scour within the low flow channel.

<u>Low Flow Channels:</u>
Low flow channels are often needed to route the last remaining runoff and dry weather flow to the outlet.

Paved/Impervious:
A paved/impervious low flow channel or bypass pipe, often used to maintain dry conditions conducive to turf, should not be used.

- The System quickly channels runoff through the basin and provides little opportunity for settling.
- Paved/impervious low flow channels also facilitate re-suspension of pollutants settled during previous storm events.

Pervious:
A pervious low flow channel allows runoff to interact with the soil and

Underdrain: If a low flow channel is necessary and a pervious low flow cannot be used, then an underdrain system may be an option.

- The underdrain should be perforated to allow runoff to infiltrate the soil.
- The underdrain should be surrounded by a bed of gravel and wrapped in a geotextile fabric to prevent siltation.

References:

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Draft Pennsylvania Stormwater Management Manual

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DuPage County
Best Management Practices Manual
Practice Standard

3.2.3.2
WET DETENTION BASINS

Blackberry Creek Watershed Alternatives Analysis Project

Definition:

A wet detention basin is a stormwater basin that includes a substantial permanent pool for water quality treatment and additional capacity above the permanent pool for runoff storage.

Purpose:

Wet detention can include full frequency or low frequency basins. The capacity for removing most urban pollutants in wet detention basins is moderate to high depending on the size of the permanent pool in relation to the surrounding drainage area. The primary pollutant removal mechanism in wet detention is sedimentation; which removes suspended pollutants such as metals, nutrients, sediments, and organics. Dissolved contaminants are removed via a combination of processes, including physical absorption to bottom sediments and suspended fine sediments, natural chemical grouping, bacterial decomposition, and uptake by aquatic plants and algae. Studies have shown that greater than 90% of pollutant removal occurs during the period between rainfall events and some removal occurs during the period when runoff enters the pond. Study projections supported by the EPA's 1993 Nationwide Urban Runoff Program (NURP) have indicated that two-thirds of the sediment, nutrients and trace metals are removed via sedimentation within 24 hours, while two weeks are required to remove a significant amount of phosphorus. Table 3-9 outlines pollutant removal efficiencies of wet detention basins.

Table 3-8 Wet Detention Basin Pollutant Removal Efficiencies

Pollutant Constituent		Pollutant Removal Efficiencies (%) for Wet Detention Basins
Solids	TSS	80
Nutrients	Total Nitrogen	33
	Total Phosphorus	51
	NO_x	43
Trace Metals	Zn	57
	Cu	66

Several design variations to enhance a wet detention basin's treatment efficiency are discussed below in the design variations section.

Site Considerations:

Drainage area, soils, slopes, and cold climate design variations are discussed below:

Drainage Area:
A wet detention basin must receive and retain enough water from rain, runoff, and groundwater to maintain a permanent pool in the deeper areas of the basin.

- Most sources recommend a minimum drainage area of ten acres to sustain a constant inflow**.**
- Precipitation in DuPage County is distributed fairly evenly throughout the year. Therefore, wet detention basins are generally effective in this area.
- Wet detention basins should be sized to treat the water quality volume and detain and release the 100-year event per the standards outlined in the DCFSPO.

Soils:
Soils within DuPage County are well suited for construction of wet basins.

- Hydrologic soil groups "C" and "D" are suitable without modification.
- Hydrologic soil groups "A" and "B" may need to be amended to reduce permeability. Soils with a high organic content should be used for all planting areas.
- Organic soils will aid in plant propagation and may hinder non-native invasive species. Organic carbon in soils provides enhanced nutrient removal.

Slopes:
Recommended basin slopes are as follows:

- The side slopes of a wet detention basin should be no steeper than 5:1 above the normal water level.
- The safety ledge of a wet basin should be no greater than 10:1.

Cold Climate Variations:
As noted with dry detention BMPs, cold climates similar to those found in northeastern Illinois can also pose many problems when designing wet detention

basins. Frozen ground throughout the tributary area to a wet pond increases impervious area. Therefore, more runoff during winter rains and snow melt will reach the basin. In addition, the volume in the permanent pool, inlets, and outlets can be reduced by the presence of ice. To counteract the effects of freezing on inlet and outlet pipes, larger diameter pipes that are resistant to frost can be used. Runoff during the winter months may have a higher pollutant load and may contain high salt concentrations due to road de-icing. Fortunately, winter rains and snow melts are generally lesser in volume than those in other seasons and will continue to be captured in their entirety in a basin designed for the 10-year event.

Design Variations:

A wet detention basin's pollutant removal effectiveness can be increased by varying depths within the permanent pool, providing sediment forebays, varying the basin shape, providing multi-stage outlets, and establishing aquatic vegetation. These topics are discussed below:

<u>Permanent Pool Depth:</u>

- A wet basin should have an average depth of 3 to 6 feet and a maximum depth of 8 feet. This depth is shallow enough to minimize thermal stratification and short-circuiting and deep enough to prevent sediment resuspension, minimize algal blooms, and maintain aerobic conditions.
- Basin depths greater than 10 ft may result in thermal stratification, and have low or no oxygen content. Therefore, if a deeper basin is needed, some form of recirculation, such as an aerator, should be provided during the summer to prevent stagnation and low oxygen conditions.
- If the wet basin is expected to be used for recreational fishing purposes, the depth should be a minimum of 10-12 ft. At least 25-50% of the pond surface area should be at this minimum depth range for sustaining warm water species such as bass and panfish and cold water species such as trout. This allows for sufficient amounts of dissolved oxygen in the winter and a range of temperatures in the summer, both of which fish need to survive. It is suggested that the pond also be a ½ acre or greater in water surface area to ensure proper growth. (MDNR: Fisheries Division)
- Shallow basins have higher sediment removal rates than deep basins. However, re-suspension of sediment by wind may result if the basin is less than 2 feet deep.
- Safety ledges, also called intermittent benches, are required to enhance public safety and to promote the growth of aquatic vegetation. Safety ledges in wet basins should be 10 feet in width and should not exceed a 10:1 slope. Safety ledge depth should range from 0"-18" below the normal water level. This elevation should be maintained to support emergent vegetation.

- Deeper water at the basin outlet will discharge cooler water and may mitigate downstream thermal effects.
- There should also be a physical separation between the forebay and permanent pool. This may be

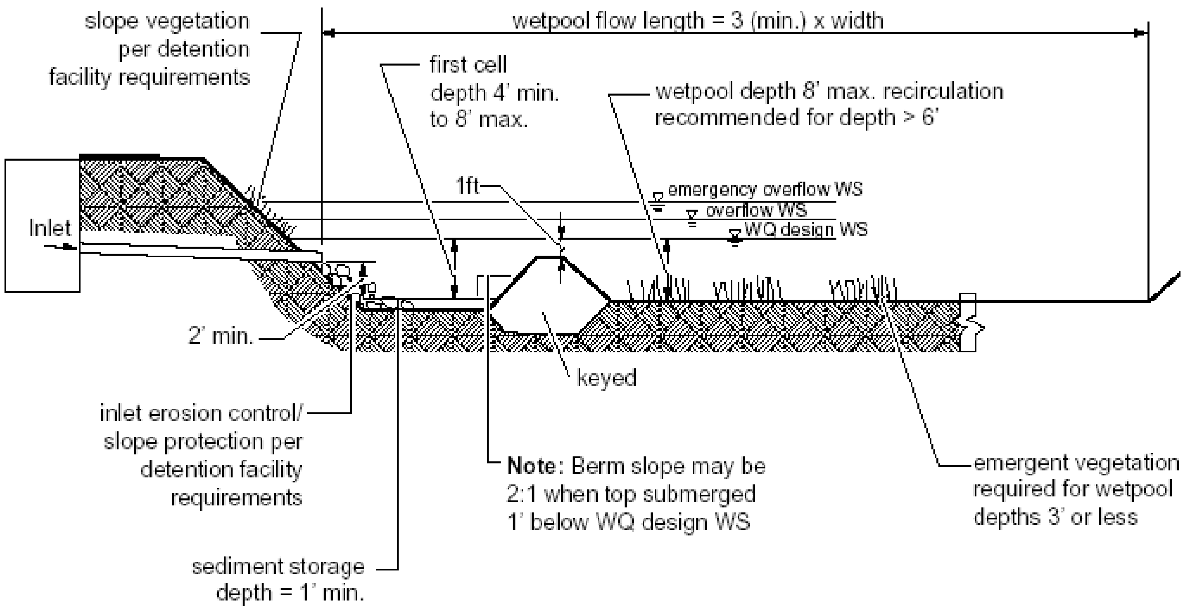

Figure 3-18 Sediment Forebay, profile view
(Stormwater management in Washington State, 2000)

achieved by installing a lateral sill with rooted wetland vegetation, two ponds in series, differential pool depth, rock-filled gabions or retaining wall, etc.

Forebays:
Wet detention basins should have a forebay at all major inflow points to capture large particle sediment, prevent sediment accumulation in the remainder of the basin, and minimize erosion caused by inflow. Periodic removal of sediment from a forebay is easier and less costly than removing sediment from the entire permanent pool.

- A forebay should contain 10-15% of the entire permanent pool volume and should be 4-8 ft deep.
- The length-to-width ratio should be at least 2:1 to reduce short-circuiting of flows.
- Vegetation in forebays can further enhance the sedimentation and reduce re-suspension and erosion.
- Inlets should be stabilized and can discharge at the surface or below the normal water level.

Surface Area & Extended Detention:
The inlet points of a wet detention basin should be as far from the outlet as possible to enhance pollutant removal capability through stormwater contact

and residence time in the permanent pool.

- A 3:1 pond length to width ratio is required to achieve pollutant removal goals.
- Underwater berms can create a longer flow path if space is limited and the basin cannot be lengthened. Increasing a wet detention basin's surface area to increase the volume as opposed to deepening the permanent pool will also enhance pollutant removal.

Extended detention can be achieved by using a multistage structure to control discharges from different size storms lengthens the residence time of smaller storm events and safely passes the 100-year event. However, more area for the detention may be needed to provide the appropriate amount of stormwater storage. Wet detention basin outlets should draw from open water areas approximately 5 to 7 feet deep.

<u>Vegetation:</u>
Vegetation is an essential part of a wet basin system. All should be planted up to 10 ft outside of the highwater level.

- To enhance the removal of soluble nutrients, sediment trapping, sediment re-suspension, and wildlife habitat the safety ledge around the perimeter of a wet pond should be planted with native wetland vegetation.
- A native vegetated buffer should be created around wet basins to protect the banks from erosion, and provide some pollutant removal before runoff enters the pond.
- If possible, existing woody vegetation and trees surrounding the pond should be preserved**.**
- The basin outlet should also be shaded to maintain cooler downstream water temperatures.
- Minimum planting diversity standards, maintenance procedures, and performance standards should be in accordance with <u>Appendix 4.4</u>.

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Best Management Practices Manual
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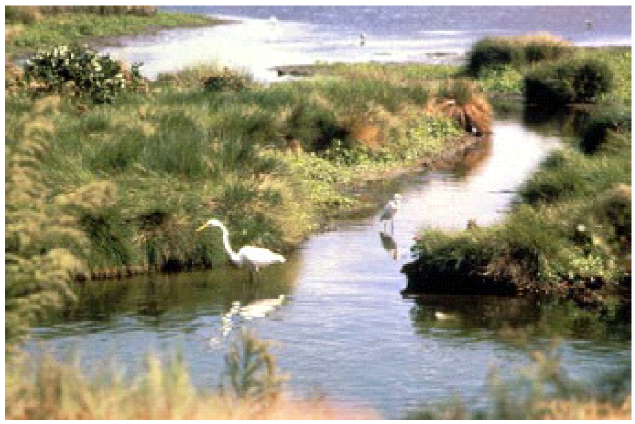
3.2.3.3
CONSTRUCTED WETLAND DETENTION BASINS



U.S. Fish and Wildlife Service

Definition:

Constructed wetland detention (CWD) basins are structural systems designed to mimic pollutant removal mechanisms of natural wetlands.

Purpose:

CWDs include shallow and deep marsh areas and may also include permanent pools for water quality treatment. Additional capacity is provided above the marsh areas and permanent pools for runoff storage. CWDs can be full frequency or low frequency basins. The capacity for removing most urban pollutants in CWDs is high, and they are the most effective practice for removal of nitrate and bacteria. Pollutant removal occurs via absorption, filtration, microbial transformation (biodegradation), precipitation, sedimentation, uptake by vegetation, and volatilization.

Table 3-10 depicts the Median pollutant removal for Constructed Wetland detention basins; however there is considerable variability in the effectiveness of the various types of CWD

Table 3-9 Constructed Wetland Pollutant Removal Efficiencies

Pollutant Constituent		Pollutant Removal Efficiencies (%) for Constructed Wetland Detention Basins
Solids	TSS	76
Nutrients	Total Nitrogen	30
	Total Phosphorus	49
	NO_x	67
Trace Metals	Zn	44
	Cu	40

Several design variations to enhance a wetland detention basin's treatment efficiency are discussed below in the design variations section.

Site Considerations:

Drainage area, soils, hydrology, slopes, cold climate design variations, and vegetation are discussed below:

<u>Drainage Area:</u>

CWDs must receive and retain enough water from rain, runoff, and groundwater to function properly.

- Most sources recommend a minimum drainage area of 10 to 25 acres to sustain a constant inflow.
- Precipitation in DuPage County is distributed fairly evenly throughout the year; therefore, CWDs are generally effective in this area.

<u>Soils:</u>

The ability of soils to retain water, support wetland vegetation, and provide active exchange sites for absorption of pollutants varies. Soils within DuPage County are typically suited for construction of CWDs. An on-site soil investigation will provide information regarding soil thickness, depth, classification, composition, drainage characteristics, erosion potential, depth to bedrock, and the location of the water table. If the soil at the wetland site is not sufficiently impermeable to prevent excessive seepage, soil modifications may be necessary.

- Hydrologic soil groups "C" and "D" are generally suitable without modification.
- Hydrologic soil groups "A" and "B" may need to be amended to reduce permeability.
- Soils with a high organic content should be used for all planting areas. Organic soils will aid in plant propagation and may hinder non-native invasive species. Organic carbon in soils also provides enhanced nutrient removal.

<u>Hydrology:</u>

CWDs should be sized to treat the water quality volume and detain and release the 100-year event per the standards outlined in the DCSFPO. A hydroperiod analysis and water budget should be performed to determine if a site has hydrologic characteristics that can support a wetland system. Too little or too much water can hinder the development of wetland vegetation. As such, the 10-year water surface elevation should not exceed the normal water level by more than 3 ft.

Slopes:

- The side slopes of a CWD basin should be no steeper than 5:1.
- If deep marsh or open water areas are proposed, a safety ledge with a slope no greater than 10:1 should be provided as a transition to the deeper water area.
- To minimize short circuiting and maximize even flow distribution, the slope across the width of the CWD should be zero (Watson & Hobson, 1989); while the slope across the length of the CWD should be essentially flat or no greater than 0.5% (Hammer, 1992).
- The length to width ratio of the basin should be at least 2:1 to prevent short circuiting. If this ratio cannot be met, the flow pathway through the CWD should be maximized.

Cold Climate Design Variations:

Cold climates similar to those found in northeastern Illinois can pose many problems when designing CWD's. Ground freezing throughout the tributary area to a CWD increases imperviousness. Therefore, more runoff during winter rains and snow melt will reach the basin. In addition, due to the shallow water depths in CWD, the volume in the wetland can be lost when the surface ices over. To counteract the effects of freezing on CWD, designing the wetland to allow continuous flow through the system will prevent pipes from freezing, larger diameter inlet and outlet pipes that are more resistant to frost can be used, and wetlands with multiple cells separated by a berm or other physical means will help retain storage for treatment above the ice layer. Runoff during the winter months may have a higher pollutant load and may contain high salt concentrations due to road de-icing. As such, salt tolerant species should be utilized where high chloride concentrations are expected.

Vegetation:

Vegetation is an essential part of a CWD basin system. It reduces the velocity of incoming stormwater, promotes sedimentation, reduces the likelihood of re-suspension of sediments, takes up nutrients and metals, and filters incoming particulates. Additionally, decaying vegetation increases the organic content of the soil and provides an aerobic zone for microbial activity that promotes the detrification process which aids in the pollutant removal process. All basins should be planted up to 10 ft outside of the high water level if able.

- To enhance removal of soluble nutrients, sediment trapping and wildlife habitat and reduce sediment re-suspension, the CWD must be planted with native wetland vegetation.
- Dense growing species with large stem surface areas provide the greatest area for stormwater contact and enhance the above mentioned pollutant removal efficiencies.
- Species that are tolerant of pollutants and water fluctuations should be used in CWD basins. Plants that are sensitive to the conditions present in CWD basins should not be utilized as they will not likely survive.
- Non-native invasive species should also not be used in CWD basins as they may negatively impact surrounding natural wetland areas.
- A native vegetated buffer should be created around wet basins to protect the banks from erosion, and provide some pollutant removal before runoff enters the CWD basin.

- If possible, existing woody vegetation and trees surrounding the basin should be preserved.
- The basin outlet should also be shaded to maintain cooler downstream water temperatures.
- Minimum planting diversity standards, maintenance procedures, and performance standards should be in accordance with Appendix 4.4.

Wetland Vegetated Pond under Construction

Completed Wetland Vegetated Pond

Design Variations:

A CWD basin's pollutant removal effectiveness can be increased by providing sediment forebays at the inlet locations, and a micropool at the outlet, providing multi-stage outlets, varying depths within the wetland, varying the basin shape, and establishing wetland vegetation.

Forebay:
CWD basins should have a forebay at all major inflow points to capture large particle sediment, prevent sediment accumulation in the remainder of the basin, and minimize erosion caused by inflow. Periodic removal of sediment from a forebay is easier and less costly than removing sediment from the entire permanent pool. A forebay should contain 10-15% of the entire permanent pool volume and should be 4-8 ft deep. The length to width ratio should be at least 2:1 to reduce short-circuiting of flows. There should also be a physical separation between the forebay and wetland area. This may be achieved by installing a lateral sill with rooted wetland vegetation, differential pool depth, rock-filled gabions or retaining wall, etc. Vegetation in forebays can further enhance the sedimentation and reduce re-suspension and erosion. Inlets should be stabilized and can discharge at the surface or below the normal water level.

Micropool & Extended Detention:
CWD basin outlets should draw from a micropool or open water area approximately 5 to 7 feet deep. Extended detention can be achieved by using a multistage structure to control discharges from different size storms, lengthens the residence time of smaller storm events and safely passes the 100-year event. However, more area for the detention may be needed to provide the appropriate amount of stormwater storage.

Depth and Shape:

Varying the depths of the wetland and designing the CWD basin with a complex configuration will aid in the reduction of pollutants via increasing surface area, preventing short circuiting by encouraging mixing, enhancing aeration of water, preventing re-suspension, minimizing thermal impacts, and improving plant diversity and health. The different depths can be classified into four zones: the open water zone, the low marsh zone, the high marsh zone, and the transitional zone. These zones are described below:

- Open water zone- may consist of a pond, micropool and/or forebay 18 inches to 6 feet in depth. The open water zone provides the majority of particulate settling in CWD basins. These areas primarily support submerged and floating vegetation.
- Low marsh zone- has a water depth of 6 to 18 inches. Several emergent wetland species are capable of growing in these conditions.
- High marsh zone- has a maximum depth of 6 inches. Due to its shallower depth, it will support a greater density and diversity of emergent species as compared to a low marsh.
- Transitional zone- is the area just above the open water and marsh zones that are inundated during storm events. As such, both wetland and upland plants can grow in these areas.

Several examples of alternating and varying the percentage of these zones are provided below:

Shallow Marsh:

Shallow marsh CWD basins consist of primarily low and high marsh zones with the only open water areas located at the forebay and micropool. These basins should be designed with sinuous pathways to increase retention time and contact with the marsh vegetation. As there is little open water area associated with Shallow Marsh CWD basins, a larger amount of land may be necessary to store the water quality storm volume. Additionally, these basins require a greater drainage area than other types to generate the flow velocities and volume changeover rates to supply the larger marsh area required to retain the water quality storm. The following figure depicts a Shallow Marsh CWD Basin:

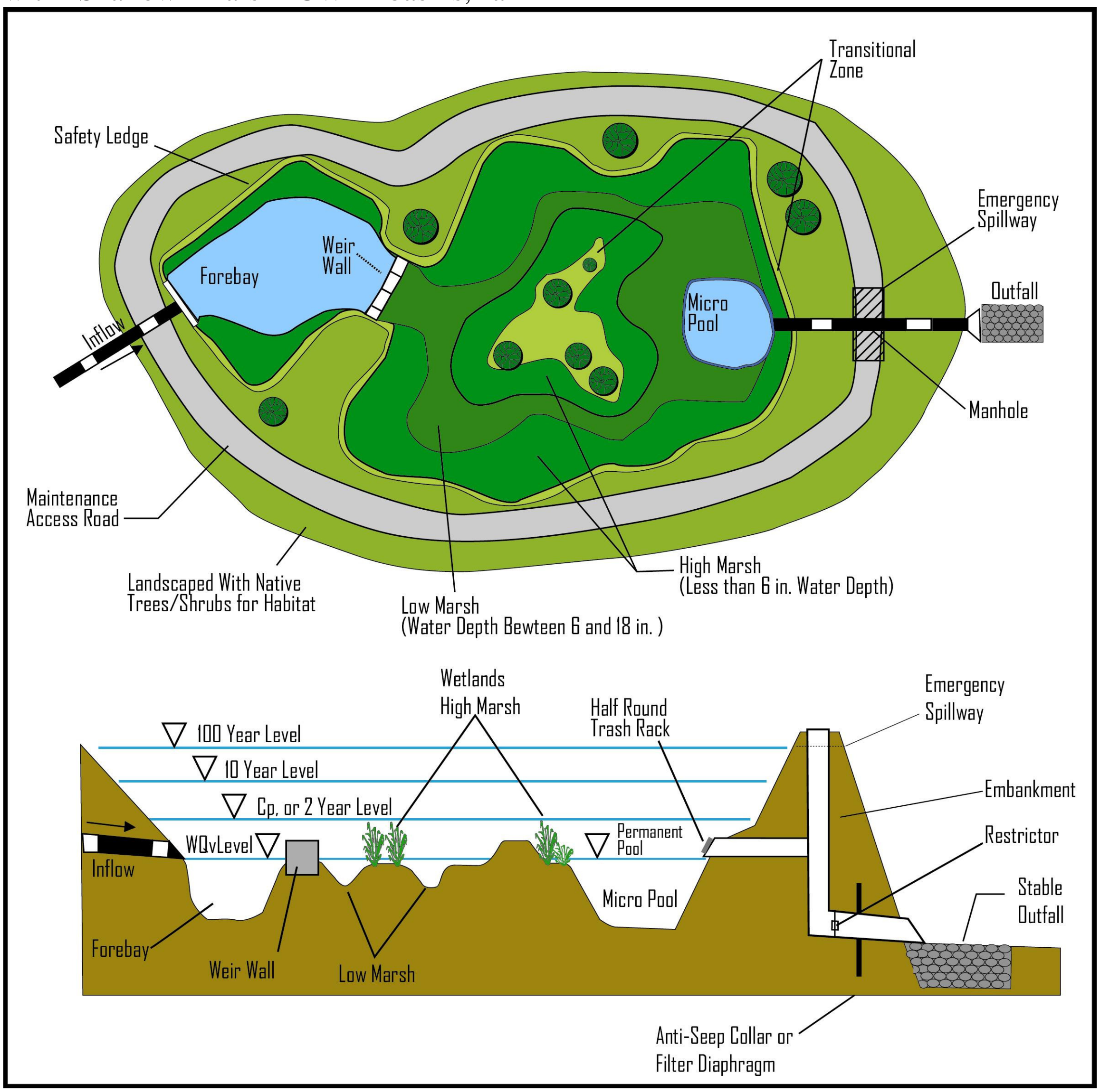


Figure 3-19 Shallow Marsh CWD
(Adapted from New York State Stormwater Management Design Manual)

If the site is small or the drainage area to the CWD basin is little, a smaller CWD basin can be constructed. The following figure depicts a small CWD basin:

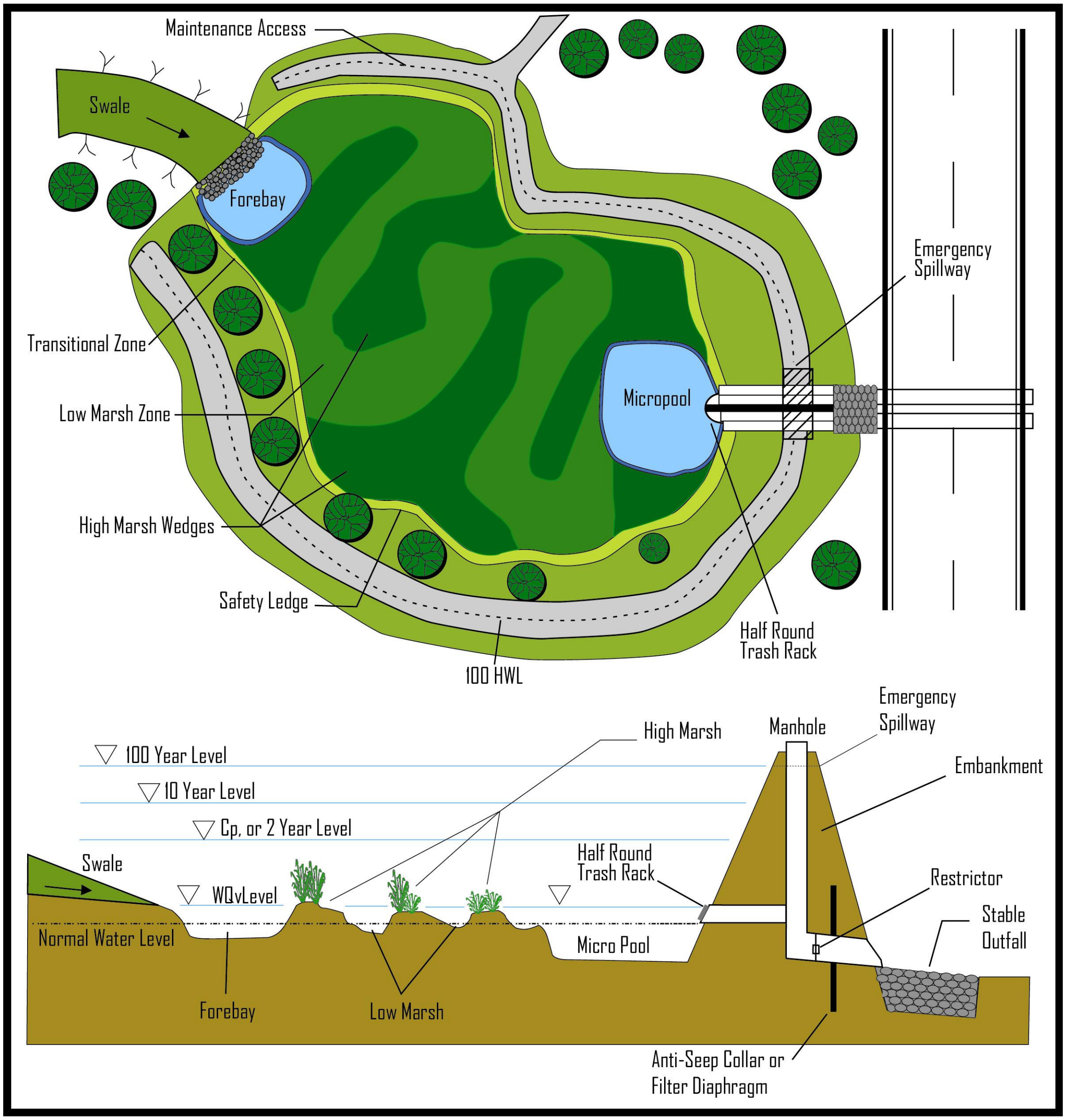


Figure 3-20 Low Tributary Area Shallow Marsh CWD
(Adapted from New York State Stormwater Management Design Manual)

Combination Pond & Shallow Marsh: This CWD basin design variation combines a wet pond and a shallow marsh. It utilizes at least one pond component in conjunction with high and low marshes. The pond is typically located at the inlet of the basin as it provides the majority of the particulate pollutant removal. The shallow marsh provides additional treatment of the soluble pollutants. As such, these designs provide a higher pollutant removal rate the other CWD basins and also require less space. The following figure depicts a Combination Pond & Shallow Marsh CWD Basin:

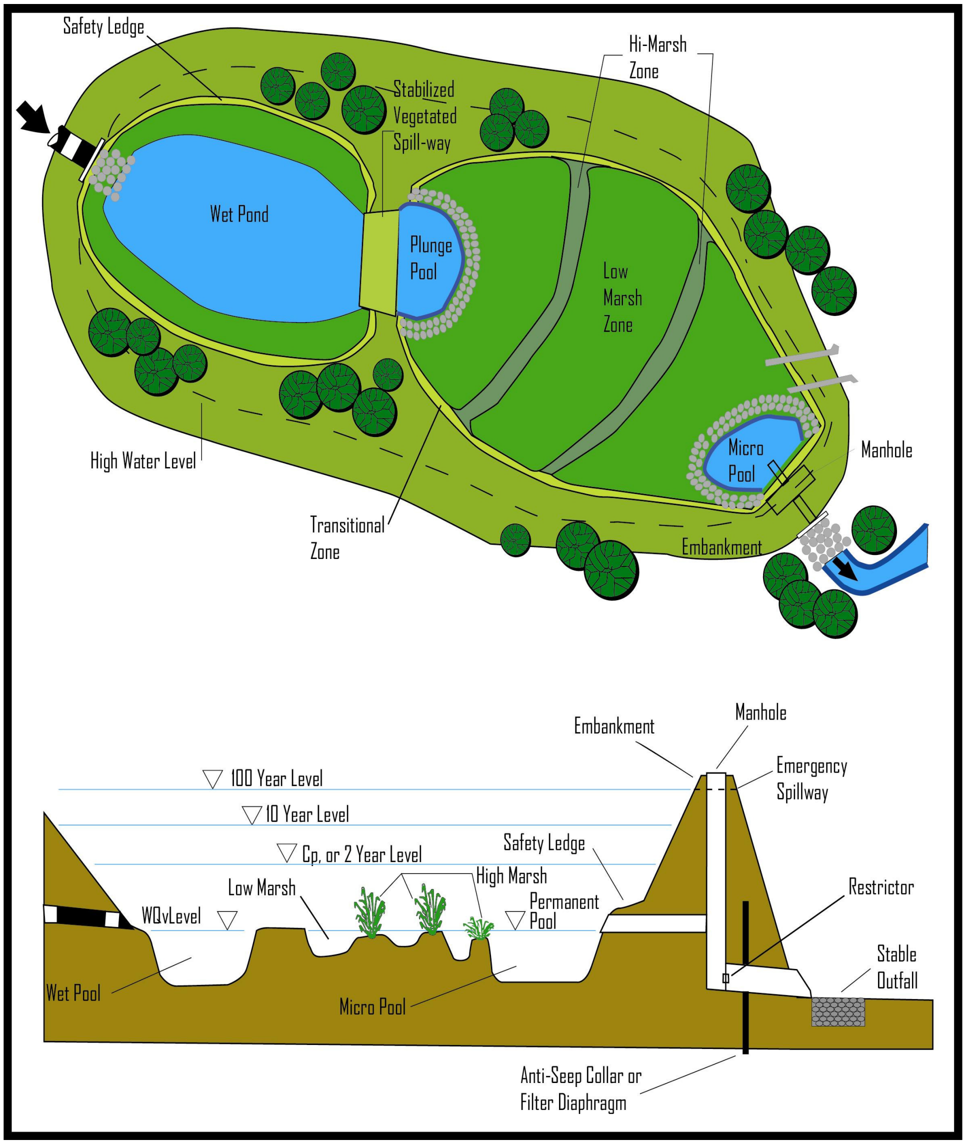


Figure 3-21 Pond/Wetland CWD
(Adapted from New York State Stormwater Management Design Manual)

Extended Wetland Detention:

Extended detention may be necessary when a site has a large off-site drainage area which is to be bypassed through the basin. As the restrictor is sized larger, it has the ability to pass the Water Quality storm at a faster rate lessening the time the basin can treat the runoff. Using a multistage structure to control discharges from different size storms lengthens the residence time of smaller storm events and safely passes the 100-year event. This design is similar to that of the shallow marsh, but temporarily stores a portion of the water quality storm in the transitional zone above the normal water level. The water level in an extended CWD basin may increase up to three feet above the normal water level, but should return to normal within 24 hours. Water levels in an extended detention CWD basin will increase more than the shallow marsh or the combination pond and wetland designs; therefore, vegetation that can withstand both flooded and dry conditions should be chosen. These systems also require less space than shallow marsh systems, as the shallow marsh storage is provided as vertical storage.

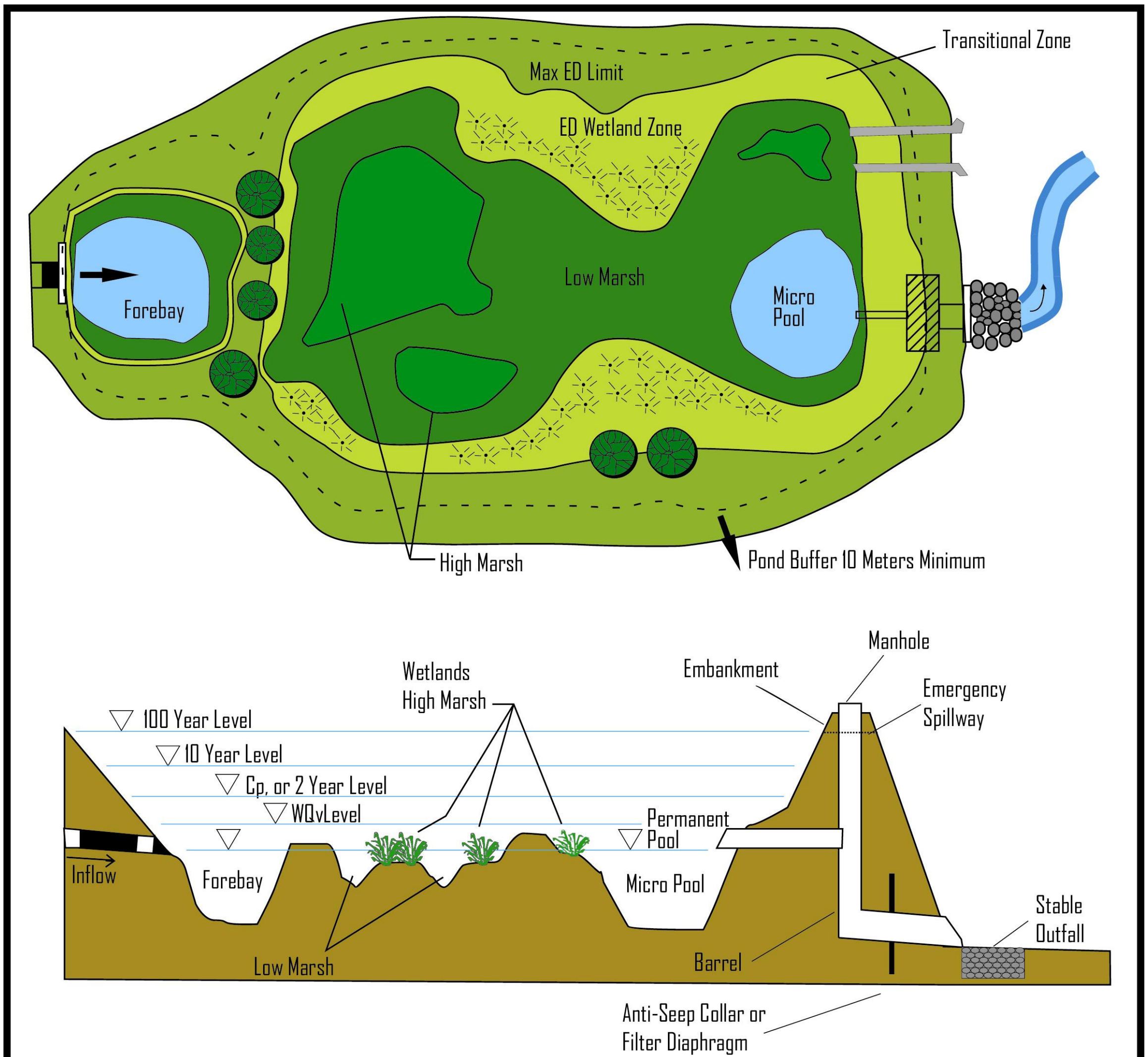


Figure 3-22 Extended Detention Wetland CWD
(Adapted from New York State Stormwater Management Design Manual)

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3.2.3.4
UNDERGROUND DETENTION BASINS

Subsurface Stormwater Management[i]

Definition:

Underground detention basins are structural systems designed to provide stormwater volume control.

Purpose:

Stormwater runoff is stored in a series of chambers or compartments. They are useful in situations where land availability is an issue. As such, they are often used in parking lots for strip malls, gas stations, downtown re-development, etc. Underground detention basins are generally full frequency basins. The capacity for removing most urban pollutants in underground detention is extremely low, and should only be used in conjunction with other BMPs in a treatment train.

Runoff rate and volume reduction:

In DuPage County, stormwater detention must control runoff rates for small storms in addition to the 100-year storm. This helps to both manage and mitigate the effects of urbanization on stormwater throughout the County reducing the potential of damage to public health, safety, life, and property caused by flooding. Providing stormwater detention minimizes increases in downstream flooding and controls high flow velocities which may cause bank erosion in downstream channels. Underground detention can provide stormwater storage for both small and large events. Some systems can also be designed to exfiltrate stored runoff into the underlying soil, which can contribute to groundwater recharge and further reduce runoff volume. These types of systems should not be used where pollutants are present that could cause groundwater pollution.

Runoff Pollution Reduction:

As the capacity for removing pollutants in underground detention is extremely low, pre-treatment or additional BMPs in a treatment train are required, especially in systems designed to exfiltrate runoff, to eliminate sediment and other solids prior to entering the underground detention basin.

Site Considerations:

Underground detention basins are designed to provide a specific predetermined amount of storage volume. The system design can range from a simple storage pipe or chamber to a complex system of multiple pipes or chambers with associated joints, crossovers, inlets, and access points. The types of materials to be used are determined by site-specific considerations and individual application conditions. Some of these considerations include the following:

- Surface loading requirements.
- Effectiveness and overall performance.
- Depth and area of allowable excavation space.
- Shape of the area available for the system.
- Depth of the water table.
- Construction costs for different materials.
- Winter weather.

Technology of these systems are constantly changing and specifications and individual performance criteria can be obtained from the manufacturers of these items. There are many different materials and systems available, each having their best fit under specific site constraints. Applicability and specifications will be reviewed on a case by case basis.

An example of an underground detention system that provides stormwater treatment in the stormwater chambers is a Subsurface Stormwater Management System which utilizes an Isolator Row™ to enhance total suspended solid removal. The isolator row is a row of open bottom chambers with perforated sidewalls that is surrounded with filter fabric. Stormwater flows from the isolator row into the surrounding stone and chambers while sediment is trapped by the filter fabric. This row is designed to capture the water quality storm via use of overflow weir when volumes exceed the capacity of the isolator row. This method can remove approximately 80% of TSS.

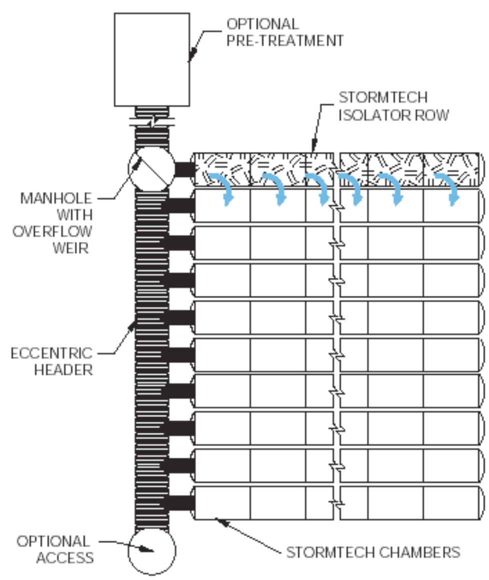

Figure 3-23 (StormTech Isolator Row with Overflow Spillway) [ii]

This system is one of many systems that may be allowed for underground detention. Many other manufacturers' underground detention systems can provide similar TSS treatment via permanent pool cells, etc. All systems must be reviewed for compliance prior to submittal.

When used in conjunction with other BMPs such as: bioswales, vegetated swales, and mechanical oil/grit separators in a treatment train, pollutants can effectively be removed.

All underground detention basins must have two 24" minimum diameter access manholes to inspect and maintain the chambers. All systems shall be inspected annually. All inspection data and reports shall be forwarded by the Owner to the proper authorities. Maintenance of underground detention systems should consist of regularly removing accumulated debris, grit, and sediments. The material removed should be tested for any toxic or hazardous waste and disposed of in accordance with local regulations regarding polluted stormwater waste. The owners of the system should provide a long term maintenance schedule during permitting.

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[i] This is a photo of one of many underground systems that may be acceptable.
[ii] The StormTech Isolator Row with Overflow Spillway System is one of many systems that may be allowed for underground detention.

3.2.4 Maintenance and Easements

Physical BMPs are by definition *stormwater facilities* in the DCSFPO. As such, the same easement and maintenance provisions that are required for facilities such as detention basins, swales, and storm sewers apply. The easement requirement does not apply to BMPs on single family residential lots. In general terms, the DCSFPO requires the following:

<u>Easements</u>
Stormwater facilities must be located within permanent easements that are dedicated to and accepted by a public entity, undivided equal interest to each land owner, or to an entity (e.g. homeowners association) acceptable to the unit of local government. Easement dedications include a plan for long-term maintenance, identification of person(s) responsible for maintenance, and dedicated funding source. In addition, easements not dedicated to the unit of local government require a reservation allowing the unit of local government to access, perform maintenance and lien property owners to recover costs should maintenance be neglected. As there is some variation in how easements are dedicated and accepted among DuPage communities, it is important to contact the community concerning the easement dedication process. For detailed information on easements and maintenance, see Section 15-180, *Long-Term Maintenance,* of the DCSFPO.

The following is example easement language for naturalized drainage and detention basin easement areas:

<u>DRAINAGE/ DETENTION AND NATURAL AREA EASEMENT PROVISIONS</u>

Declarant hereby reserves and grants to The COUNTY OF DUPAGE easements over stormwater facilities and vegetation, together with reasonable access thereto. Said easements shall be perpetual and shall run with the land and shall be binding upon the declarant, its successors, heirs, executors and assigns. To ensure the integrity of the stormwater facilities and "natural" areas, no obstruction shall be placed, nor alterations made, including alterations in the final topographical grading which in any manner impede or diminish stormwater drainage or detention in, over, under, through or upon said easement areas. In the event such obstruction or alterations are found to exist, or if the property owner otherwise fails to properly maintain the stormwater facilities and drainage easements or change the character of the proposed native vegetation, the Village shall, upon seventy- two (72) hours prior notice to the property owner (or any owner of property within the subdivision), have the right, but not the duty, to perform, or have performed on its behalf, any maintenance work to or upon the stormwater facilities and "natural" areas and drainage easements or to remove said obstruction or alterations or to perform other maintenance, repair, alteration or replacement as may reasonably to ensure that adequate stormwater storage, storm drainage, detention and retention facilities, "natural" areas and appurtenances thereto remain fully operational and that the condition of said drainage easements complies with all the applicable COUNTY codes. In the event of an emergency situation, as determined by the COUNTY, the seventy-two (72) hours prior notice requirement set forth above shall not apply and the COUNTY shall have the right, but not the duty, to proceed without notice to the property owner.

In the event the COUNTY shall be required to perform, or have performed on its behalf any maintenance work to or upon the stormwater facilities and/or "natural" areas, and drainage easements as set forth in this declaration, or any removal or alteration as aforesaid, the cost of such work shall, upon recordation of Notice of Lien with the Recorder of Deeds of DuPage County, Illinois, constitute a lien against the assets of the property owner and against the drainage easements as well as each and every lot within the subdivision. In addition, the area disturbed by said maintenance operations, shall be re-planted with the same plantings as proposed in the COUNTY Permit No. _____________.

The cost of the work incurred by DuPage COUNTY shall include all expenses and costs associated with the performance of such work including, but not limited to, reasonable engineering, consulting and attorneys' fees related to the planning and actual performance of the work.

If it is determined by the property owner that alterations to the stormwater facilities and/or "natural" areas within drainage easements are necessary to properly maintain the integrity of the stormwater facilities, the COUNTY shall be notified by the property owner of said proposed alteration. No such alteration shall take place without the prior approval from the COUNTY. The COUNTY may, in its direction, require the submittal of plans and specifications for COUNTY approval before said alteration may take place.

<u>Maintenance</u>
Minimum planting diversity standards, long-term maintenance procedures, and performance standards should be in accordance with Appendix 4.4.

Section 4

APPENDICES

4.1 BMP Selection Guide

PERMANENT BMPs BY LAND-USE

The following BMP selection guide is intended to provide a convenient method of selecting permanent BMPs for inclusion in the Site Stormwater Plan of a DCSFPO Stormwater Management Permit Submittal. Permanent BMPs are those practices that address the water quality issues associated with the long term use of a property. Therefore, the guide does not address BMPs such as construction site erosion and sediment control practices or temporary or more transient practices and landscape features such as rain barrels and water gardens. The selection guide is divided into five individual guides representing various common types of land use and the stormwater detention requirement thresholds of the DCSFPO.

- Each land use selection guide lists generally acceptable BMPs that treat three general categories of pollutants.
- Each land use selection guide assigns individual BMPs numerical **values** based on their ability to mitigate each of the three categories of pollutants.
- Each land use selection guide ranks the **importance** of treating each of the three pollutant categories in order to account for the differences in land use.

Selecting a BMP, or suite of BMPs that equal or exceed a certain average **importance value,** and which fully treat the target pollutant categories, provides reasonable assurance that the design will meet the BMP Site Runoff Requirements found in Section 15-113.11 of the DCSFPO. This guide should be used in consultation with relevant sections of this Manual to help ensure that the selected BMPs are appropriate, cost effective and efficiently utilized.

Note that the Selection Guide is, as its title portrays, a guide useful in providing guidance in the selection process. This guidance is based on certain generalizations as to the application and efficiency of the featured BMPs. It is important to realize that there are many different variations in the application of BMPs in a stormwater pollution plan. The abilities of the design professional, budget, and physical site characteristics all influence how successful the design may be. While a certain BMP may be listed with a "moderate" Importance Value (2) or "low" value (1), this judgment is made assuming typical limitations. For instance, drywells are commonly limited in their treatment volume as they are typically designed to a very frequent (first flush) design storm. Larger systems are usually precluded due to cost and physical size. However, with an unlimited budget and ideal site conditions, they could play a more important role in the stormwater pollution plan. Professional expertise must be used in the design and review of the stormwater pollution plan to fully evaluate its suitability.

It is also important to note that this selection guide is not all inclusive and its use is not mandatory under the DCSFPO. As such, BMP methods not present within the manual will be reviewed by DuPage County Staff or Ordinance Administrator in a waiver community and a value will be established based upon a comparison of pollutant removal efficiencies of other BMPs within the manual.

Mandatory BMPs for all Land-Use

Mandatory BMPs

Consider avoidance and minimization of activities that cause pollutants to become entrained in stormwater runoff (See Manual Section 3.2.1).

Maintenance: identification of responsible parties, maintenance tasks, and funding source(s), (See DCSFPO Section 15-180, *Long-Term Maintenance*).

Individual Single Family Residential Lots, Any Size

Pollutant Category by Treatment Importance

More Important ↓ Less Important

Nutrients

TSS

Metals/Oils

Recommended BMPs	Value	Pollutant Treatment Limitation	Notes
Vegetated Swale, native vegetation	3	None	
Vegetated Swale, native w/ under drain	3	None	
Filter Strip 25' min, native vegetation	3	None	
Vegetated Swale, turf w/ under drain	3	None	
Dry Well	2	None	
Permeable Paver Driveway	2	Nutrients	Select additional BMP(s) to address limitation

Importance Value (BMP Effectiveness)

1 = Low 2 = Moderate 3 = High

Notes:

- BMPs should treat at least 100% of the developed area with a 2.5 or greater average importance value.
- Importance values that average < 2.5 due to impracticability of providing on-site BMPs may be required to pay a fee for use by the community in providing off-site BMPs.
- In the instance that the lot is located within a subdivision where an off-site BMP is currently located, credit will be given for the off-site BMP dependant on the effectiveness and condition of the BMP as determined by the administrator.

< 1 Acre Multi-Family or Non-Residential Land Uses and Roadways

Pollutant Category by Treatment Importance

More Important — **TSS**

Metals/Oils

Less Important — **Nutrients**

Recommended BMPs	Value	Pollutant Treatment Limitation	Notes
Vegetated Swale, turf, w/ under drain	2	Metals/Oil	Select additional BMP(s) to address limitation
Vegetated Swale, native	2	Metals/Oil	Select additional BMP(s) to address limitation
Vegetated Swale, native w/ under drain	3	None	
Vegetated Swale, native w/ check dam	3	None	
Filter Strip 25’ min. width, turf	2	Oil	Select additional BMP(s) to address limitation
Filter Strip 25’ min. width, native	3	None	
Infiltration	3	Oil	Select additional BMP(s) to address limitation
Permeable Pavers	3	None	
Manufactured (e.g. grit/oil separator)	Varies	Varies	Submit manufacturer’s specifications.

Importance Value (BMP Effectiveness)

1 = Low   2 = Moderate   3 = High

Notes:

- BMPs should treat at least 100% of the developed area and equal 2.5 or greater average importance value.
- Importance values that average < 2.5 due to impracticability of providing on-site BMPs may be required to pay a fee for use by the community in providing off-site BMPs.

> 1 Acre Multi-Family or Non-Residential Land Uses; Roads w/ Detention

Pollutant Category by Treatment Importance

More Important — TSS

Metals/Oils

Less Important — Nutrients

Recommended BMPs	Value	Pollutant Treatment Limitation	Notes
Vegetated Swale, turf w/ under drain	2	Metals/Oil	Select additional BMP(s) to address limitation
Vegetated Swale, native	2	Metals/Oil	Select additional BMP(s) to address limitation
Vegetated Swale, native w/ under drain	3	None	
Vegetated Swale, native, w/ check dam	3	None	
Filter Strip 25' min. width, turf	2	Oil	Select additional BMP(s) to address limitation
Filter Strip 25' min. width, native	3	None	
Infiltration	3	Oil	Select additional BMP(s) to address limitation
Permeable Pavers	3	None	
Dry Detention, turf	1	Oil	Select additional BMP(s) to address limitation
Dry Detention, native	2	Oil	Select additional BMP(s) to address limitation
Wet Bottom Detention, native	2	Oil	Select additional BMP(s) to address limitation
Wetland Detention (no open water)	2	None	Poor winter performance
Constructed Wetland (CWD)	3	None	
Manufactured	Varies	Varies	Submit manufacturer's specifications

Importance Value (BMP Effectiveness)

1 = Low 2 = Moderate 3 = High

Notes:

- BMPs should treat 100% of the developed area and average or exceed a 2.5 average importance value.

> 1 Acre Single or Two-Family Residential Subdivisions

Pollutant Category by Treatment Importance

More Important → Less Important

- TSS
- Nutrients
- Metals/Oils

Recommended BMPs	Value	Pollutant Treatment Limitation	Notes
Vegetated Swale, turf w/ under drain	2	None	
Vegetated Swale, native	2	None	
Vegetated Swale, native w/ under drain	3	None	
Vegetated Swale, native, w/ check dam	3	None	
Filter Strip 25' min. width, turf	2	Nutrients	Select additional BMP(s) to address limitation
Filter Strip 25' min. width, native	3	None	
Infiltration	3	None	
Permeable Pavers	3	None	
Dry Detention, turf	1	None	Poor winter performance
Dry Detention, native	2	None	Poor winter performance
Wet Bottom Detention, native	2	None	
Wetland Detention (no open water)	2	None	Poor winter performance
Constructed Wetland (CWD)	3	None	
Manufactured	Varies	Varies	Submit manufacturer's specifications

Importance Value (BMP Effectiveness)

1 = Low 2 = Moderate 3 = High

Notes:

- BMPs should treat 100% of the developed area and average or exceed a 2.0 average importance value

Parks, and Other Pervious Land-Use

Pollutant Category by Treatment Importance

More Important

Nutrients

TSS

Less Important

Recommended BMPs	Value	Pollutant Treatment Limitation	Notes
Vegetated Swale, turf w/ underdrain	2	Metals/Oil	Select additional BMP(s) to address limitation
Vegetated Swale, native	2	None	
Vegetated Swale, native w/ under drain	3	None	
Vegetated Swale, native, w/ check dam	3	None	
Filter Strip 25' min. width, turf	2	Nutrients	Select additional BMP(s) to address limitation
Filter Strip 25' min. width, native	3	None	
Infiltration	3	None	
Dry Detention, turf	1	None	Poor winter performance
Dry Detention, native	2	None	Poor winter performance
Wet Bottom Detention, native	2	None	Select additional BMP(s) to address limitation
Wetland Detention (no open water)	2	None	Poor winter performance
Constructed Wetland (CWD)	3	None	

Importance Value (BMP Effectiveness)

1 = Low 2 = Moderate 3 = High

- BMPs should treat 100% of the developed area and average or exceed a 2.0 average importance value.
- Proposed impervious areas associated with parks and similar developments should be evaluated as a non-residential land use.

Examples

1. Individual Residential Lots, Any Size.

A new house is to be constructed on a 1/3 acre lot. BMPs chosen are a pervious paver driveway and a dry well (soakaway pit). 100% of the developed area will be treated with these two bmps.

Selection Guide Result: The plan meets the 100% of the developed area treatment criteria but the average importance value for these particular BMPs is only 2.0. It is unlikely that these two BMPs alone will provide an adequate level of treatment. Drywells are usually designed to a frequent (first flush) design storm and therefore lose their ability to treat runoff when their design capacity is reached. Pervious pavers may not perform well under winter conditions and cannot be utilized to treat nutrient laden runoff (such as that generated by residential lawns. Due to these limitations, their importance value is lower.

Solution: BMPs must be chosen that individually, or in combination, treat 100% of the developed area with at least a 2.5 average importance value. In this case, adding a vegetated swale or filter strip (3.0 importance value) for the site area being treated by the pervious paver drive would meet the minimum criteria. Keeping the pervious paver drive would not lower the average importance value as it exceeds the minimum criteria of 100% of the developed area treatment.

2. Single Family Residential Subdivision of 8.0 Acres in Size.

As this subdivision triggers the 3 acre detention threshold limit of the DCSFPO, 100% of the developed area must be treated. BMPs chosen are native vegetated swale with a check dam (Importance value 3) and a dry detention pond (importance value 1).

Selection Guide Result: At first glance it appears that the pollution prevention plan meets the requirement- 100% of the developed area is being treated at a 2.0 average importance value. However, care must be taken to ensure that the selected BMPs are being utilized in an efficient and effective manner. In this case, if 10% of the site runoff was being treated with the vegetated swale and check dam, and the remainder of the site runoff was treated by no other BMP except the dry detention pond, clearly this would not be an effective pollution prevention plan and would run contrary to the guidance provided in the manual.

APPENDIX 4.2

TABLES & FIGURES

APPENDIX 4.3

NATIVE SEED MIXES

The following are examples of appropriate seed mixes, trees, and shrubs available from nurseries for various BMP uses. More examples of appropriate species are available at http://plants.usda.gov/ and from nurseries that specialize in native plantings. All seed mixes for use in BMP and existing natural areas shall be provided to DuPage County for review and approval. Additionally, "Plants for Stormwater Design: Species Selection for the Upper Midwest'" is an exceptional resource for planning species location. That document provides valuable information on plant tolerance to inundation depth and drawdown time, as well as pollutant tolerance levels. Plants should be chosen based upon the anticipated conditions determined by the inundation duration analysis discussed in Section 3.2.3.

Generally, seed mixes should be drill seeded at approximately 10-15 pounds per acre. If the seed is hand broadcast it should occur at twice the drill seed rate. The temporary cover crop should be seeded at a rate of 25 pounds per acre. The cover crop matrix should be planted throughout the planting areas immediately after project completion to prevent erosion if conditions are not conducive for native species seeding. Permanent native species should be dormant seeded if possible or seeded during the first available growing season at the appropriate time and conditions for such plantings. The seed should be lightly raked in, rolled, and watered.

All trees should be between 2½-4" caliper and all shrubs will be a 5 gallon minimum. Woody plant installation should occur prior to seed installation. Holes for all trees should be 2 times the ball width. Holes for all shrubs should be dug with a 6" minimum around all sides of the ball. The burlap should be removed from all bare root stock trees and shrubs, whereas, if balled and burlaped the twine around the trunk should be removed and burlap may remain. All trees and shrubs should be planted in the plumb position and have nursery tags with the species name for easy future identification. Within five days of planting, a mulch saucer should be placed around all trees and shrubs for watering.

Emergent Seed Mix	
Scientific Name	**Common Name**
Temporary Cover:	
Agrostis alba	RED TOP
Agrostis alba palustris	BENT GRASS
Avena sativa	SEED OATS
Lolium multiflorum	ANNUAL RYE
Permanent Grasses, Sedges, & Rushes:	
Carex comosa	BRISTLY SEDGE
Echinochloa crusgalli	BARNYARD GRASS
Eleocharis smallii	MARSH SPIKE RUSH
Eleocharis erythropoda	RED-ROOTED SPIKE RUSH
Juncus effusus	COMMON RUSH
Leersia oryzoides	RICE CUT GRASS
Scirpus acutus	HARD-STEMMED BULRUSH
Scirpus fluviatilis	RIVER BULRUSH
Scirpus pungens	CHAIRMAKER'S RUSH
Scirpus validus creber	GREAT BULRUSH
Sparganium eurycarpum	COMMON BUR REED
Spartina pectinata	PRAIRIE CORD GRASS
Forbs:	
Acorus calamus	SWEET FLAG
Alisma subcordatum	COMMON WATER PLANTAIN
Glyceria grandis	REED MANNA GRASS
Iris virginica shrevei	BLUE FLAG
Peltandra virginica	ARROW ARUM
Polygonum punctatum	SMARTWEED
Pontederia cordata	PICKEREL WEED
Sagittaria latifolia	COMMON ARROWHEAD

Note: Emergent seed should not be installed if standing water is present unless provisions are made for controlling the water level at a fresh mud condition for at least a month. If provisions for water level manipulation cannot be made planting plugs at a rate of 3, 500 to 4,000 plugs per acre is the recommended planting method.

Mesic to Dry Savanna w/ Flowers Mix	
Scientific Name	**Common Name**
Temporary Cover:	
Avena sativa	SEED OATS
Permanent Grasses, Sedges, & Rushes:	
Bromus latiglumis	EAR-LEAFED BROME
Bromus pubescens	WOODLAND BROME
Carex blanda	COMMON WOOD SEDGE
Diarrhena americana	BEAK GRASS
Elymus canadensis	CANADA WILD RYE
Elymus virginicus	VIRGINIA WILD RYE
Festuca obtusa	NODDING FESCUE
Hystrix patula	BOTTLEBRUSH GRASS
Juncus dudleyi	DUDLEY'S RUSH
Forbs:	
Agastache scrophulariaefolia	PURPLE GIANT HYSSOP
Anemone virginiana	TALL ANEMONE
Aquilegia canadensis	COLUMBINE
Arisaema triphyllum	JACK-IN-THE-PULPIT
Aster lateriflorus	CALICO ASTER
Aster sagittifolius	ARROW-LEAFED ASTER
Aster shortii	SHORT'S ASTER
Baptisia leucantha	WHITE INDIGO
Campanula americana	TALL BELLFLOWER
Clematis virginiana	VIRGIN'S BOWER
Echinacea Purpurea	PURPLE CONEFLOWER
Erythronium albidum	WHITE TROUT LILY
Eupatorium purpureum	PURPLE JOE PYE WEED
Hypericum pyramidatum	GREAT ST. JOHN'S WORT
Lobelia inflata	INDIAN TOBACCO
Penstemon digitalis	FOXGLOVE BEARDTONGUE
Polygonatum canaliculatum	SMOOTH SOLOMON'S SEAL
Pycnanthemum pilosum	HAIRY MT. MINT
Ratibida pinnata	YELLOW CONEFLOWER
Rudbeckia hirta	BLACK-EYED SUSAN
Silphium integrifolium	ROSINWEED
Smilacina racemosa	FEATHERY FALSE SOLOMON'S SEAL
Solidago flexicaulis	ZIGZAG GOLDENROD
Solidago juncea	EARLY GOLDENROD
Tradescantia ohioensis	OHIO SPIDERWORT
Trillium recurvatum	RED TRILLIUM
Triosteum perfoliatum	LATE HORSE GENTIAN
Verbena urticifolia	WHITE VERVAIN
Veronicastrum virginicum	CULVER'S PHYSIC
Zizia aurea	GOLDEN ALEXANDER

Low Profile Mesic Prairie	
Scientific Name	**Common Name**
Temporary Cover:	
Avena sativa	SEED OATS
Lolium multiflorum	ANNUAL RYE
Permanent Grasses:	
Agropyron trachycaulum	SLENDER WHEAT GRASS
Andropogon scoparius	LITTLE BLUESTEM
Bouteleloua curtipendula	SIDE-OATS GRAMMA
Carex annectens	YELLOW-FRUITED SEDGE
Carex bicknellii	BICKNELL'S SEDGE
Carex brevior	SHORT SEDGE
Elymus canadensis	CANADA WILD RYE
Panicum virgatum	SWITCH GRASS
Sporobolus heterolepis	PRAIRIE DROPSEED
Sorghastrum nutans	INDIAN GRASS
Forbs:	
Amorpha canescens	LEADPLANT
Aster azureus	SKY BLUE ASTER
Aster laevis	SMOOTH BLUE ASTER
Aster novae-angliae	NEW ENGLAND ASTER
Baptisia leucantha	WHITE INDIGO
Cassia fasciculata	PARTRIDGE PEA
Echinacea Pallida	PALE PURPLE CONEFLOWER
Eryngium yuccifolium	RATTLESNAKE MASTER
Heliopsis helianthoides	EARLY SUNFLOWER
Hypericum pyramidatum	GREAT ST. JOHN'S WORT
Lespedeza capitata	ROUNDHEAD BUSHCLOVER
Liatris aspera	BUTTON BLAZINGSTAR
Liatris pycnostachya	PRAIRIE BLAZINGSTAR
Monarda fistulosa	PRAIRIE BERGAMOT
Parthenium integrifolium	WILD QUININE
Penstemon digitalis	FOXGLOVE BEARDTONGUE
Petalostemum purpureum	PURPLE PRAIRIE CLOVER
Physostegia virginiana	FALSE DRAGONHEAD
Potentilla arguta	PRAIRIE CINQUEFOIL
Ratibida pinnata	YELLOW CONEFLOWER
Rosa blanda	EARLY WILD ROSE
Rudbeckia hirta	BLACK-EYED SUSAN
Rudbeckia subtomentosa	SWEET CONEFLOWER
Silphium integrifolium	ROSINWEED
Solidago nemoralis	OLDFIELD GOLDENROD
Solidago riddellii	RIDDELL'S GOLDENROD
Solidago rigida	STIFF GOLDENROD
Tradescantia ohioensis	OHIO SPIDERWORT
Virbena stricta	HOARY VERVAIN
Vernonia fasciculata	COMMON IRONWEED
Vernonia missurica	MISSORI IRONWEED
Veronicastrum virginicum	CULVER'S PHYSIC

Native Salt Tolerant/Roadside List	
Plants less than 2 ft tall	
Scientific Name	**Common Name**
Temporary Cover:	
Avena sativa	SEED OATS
Lolium multiflorum	ANNUAL RYE
Permanent Grasses:	
Agrostis gigantea	REDTOP
Andropogon scoparius	LITTLE BLUESTEM GRASS
Echinochloa crusgalli	BARNYARD GRASS
Elymus canadensis	CANADA WILD RYE
Juncus balticus littoralis	LAKE SHORE RUSH
Juncus interior	INLAND RUSH
Panicum dichotomiflorum	KNEE GRASS
Panicum virgatum	SWITCH GRASS
Festuca obtusa	NODDING FESCUE
Forbs:	
Asclepias syriaca	COMMON MILKWEED
Asclepias verticillata	WHORLED MILKWEED
Aster ericoides	HEATH ASTER
Aster novae-angliae	NEW ENGLAND ASTER
Cassia fasciculata	PARTRIDGE PEA
Coreopsis palmata	PRAIRIE COREOPSIS
Gaura biennis	BIENNIAL GAURA
Monarda fistulosa	WILD BERGAMOT
Solidago altissima	TALL GOLDENROD
Solidago rigida	STIFF GOLDENROD

Shoreline Seed Mix	
Scientific Name	**Common Name**
Temporary Cover:	
Agrostis alba	REDTOP
Avena sativa	SEED OATS
Lolium multiflorum	ANNUAL RYE
Permanent Grasses:	
Carex vulpinoidea	BROWN FOX SEDGE
Carex comosa	BRISTLY SEDGE
Eleocharis palustris major	GREAT SPIKE RUSH
Elymus canadensis	CANADA WILD RYE
Elymus virginicus	VIRGINIA WILD RYE
Glyceria striata	FOWL MANNA GRASS
Leersia oryzoides	RICE CUT GRASS
Scirpus atrovirens	DARK GREEN RUSH
Spartina pectinata	PRAIRIE CORD GRASS
Forbs:	
Alisma subcordatum	COMMON WATER PLANTAIN
Asclepias incarnata	SWAMP MILKWEED
Aster simplex	PANICLED ASTER
Bidens sp.	BIDENS, VARIOUS
Eupatorium perfoliatum	COMMON BONESET
Helenium autumnale	SNEEZEWEED
Lobelia siphilitica	GREAT BLUE LOBELIA
Ludwigia alternifolia	SEEDBOX
Solidago gigantea	LATE GOLDENROD
Verbena hastata	BLUE VERVAIN

Short Mesic to Dry Prairie	
Plants less than 2 ft tall	
Scientific Name	**Common Name**
Temporary Cover:	
Avena sativa	SEED OATS
Lolium multiflorum	ANNUAL RYE
Permanent Grasses:	
Bouteloua curtipendula	SIDE-OATS GRAMA
Carex bebbii	BEBB'S OVAL SEDGE
Carex brevior	PLAINS OVAL SEDGE
Carex granularis	PALE SEDGE
Carex rosea	CURLY-STYLED WOOD SEDGE
Cyperus esculentus	FIELD NUT SEDGE
Eragrostis spectabilis	PURPLE LOVE GRASS
Festuca obtusa	NODDING FESCUE
Sporobolus heterolepis	PRAIRIE DROPSEED
Forbs:	
Allium canadense	WILD ONION
Allium cernuum	NODDING WILD ONION
Anemone canadensis	MEADOW ANEMONE
Anemonella thalictroides	RUE ANEMONE
Asclepias tuberosa	BUTTERFLY WEED
Asclepias verticillata	WHORLED MILKWEED
Aster macrophyllus	BIG-LEAVED ASTER
Aster ptarmicoides	STIFF ASTER
Aster sericeus	SILKY ASTER
Coreopsis palmata	PRAIRIE COREOPSIS
Dodecatheon meadia	SHOOTING STAR
Geranium maculatum	WILD GERANIUM
Geum triflorum	PRAIRIE SMOKE
Hypericum sphaerocarpum	ROUND-FRUITED ST. JOHN'S WORT
Juncus dudleyi	DUDLEY'S RUSH
Juncus interior	INLAND RUSH
Juncus tenuis	PATH RUSH
Liatris cylindracea	CYLINDRICAL BLAZING STAR
Lupinus perennis occidentalis	WILD LUPINE
Monarda punctata	HORSE MINT
Opuntia humifusa	EASTERN PRICKLY PEAR
Penstemon hirsutus	HAIRY BEARD TONGUE
Phlox divaricata	WOODLAND PHLOX
Ranunculus fascicularis	EARLY BUTTERCUP
Silene stellata	STARRY CAMPION
Silene virginica	FIRE PINK
Sisyrinchium angustifolium	STOUT BLUE-EYED GRASS
Solidago caesia	BLUE-STEMMED GOLDENROD
Solidago speciosa	SHOWY GOLDENROD
Thalictrum dioicum	EARLY MEADOW RUE
Tradescantia virginiana	VIRGINIA SPIDERWORT
Zizia aptera	HEART-LEAVED MEADOW PARSNIP

Native Shrubs

Species Name	Common Name	Environment	Exposure	General Info		Other
				Height (ft)	Width (ft)	
Amorpha fruiticosa	Indigo Bush	Wet/Mesic-Hydric	Full sun	8	6	Fixes nitrogen, pretty ingo flowers
Cephalanthus occidentalis	Buttonbush	Mesic-Hydric	Full sun	12	12	Attracts butterflies
Cornus alternifolia	Pagoda Dogwood	Mesic-Wet/Mesic	Shade-Morning sun	15	15	Great wildlife food value
Cornus obliqua	Blue-fruited Dogwood	Wet/Mesic-Hydric	Full sun	12	15	Great wildlife food value
Cornus stolonifera	Red Osier Dogwood	Wet/Mesic-Hydric	Full sun	8	10	Brite red stems in winter
Physocarpus opulifolius	Ninebark	Dry/Mesic - Mesic	Part Shade-Full Sun	10	10	Durable, Winter color
Rosa palustris	Swamp Rose	Mesic-Wet/Mesic	Full sun	6	5	Rose hips in winter
Sambucas canadensis	Elderberry	Dry/Mesic-Wet/Mesic	Part Shade-Full Sun	10	8	Durable, human and bird food value
Vibernum dentatum	Arrowwood Vibernum	Dry/Mesic-Mesic	Part Shade-Full Sun	10	8	food value nice on side slopes
Vibernum lentago	Nannyberry	Mesic-Wet/Mesic	Part Shade-Full Sun	15	10	Great wildlife food value
Vibernum prunifolium	Blackhaw	Dry/Mesic-Wet/Mesic	Part Shade-Full Sun	15	12	Fall color, Food Value, Screening

Native Trees

Species Name	Common Name	Environment	Exposure	General Info		Other
				Height (ft)	Width (ft)	
Betula nigra	River Birch	Mesic-Hydric	Full sun	40	30	pH 6.5 best
Celtis occidentalis	Hackberry	Xeric-Wet/Mesic	Full sun	60	50	Fast growing
Cratagus mollis	Downy Hawthorn	Xeric-Wet/Mesic	Shade-Full sun	25	25	Good in poor soils
Fraxinus pennsylvanica	Green ash	Mesic-Hydric	Full sun	60	50	
Quercus bicolor	Swamp White Oak	Mesic-Hydric	Full sun	85	85	Gets very large in moist sites
Quercus macrocarpa	Bur Oak	Dry/Mesic-Wet/Mesic	Full sun	85	100	
Quercus palustris	Pin Oak	Mesic-Hydric	Full sun	80	80	

APPENDIX 4.4

NATIVE LANDSCAPE REQUIREMENTS

General Landscape Requirements.

a. All plants specified, except temporary cover crop, shall be native to the North Central Region of the United States.

b. A diverse planting list with at least 20 species, which may include native grasses, rushes, sedges, and forb species, shall be included in the planting area. Native trees and shrubs are encouraged.

c. Seventy percent (70%) of native non-woody species shall have a mature height of at least 30” to provide sufficient plant height and density for goose control when used adjacent to detention basins and other open water areas. The height of vegetation may vary due to runoff velocity and environmental factors when used in other BMPs such as: vegetated filter strips, swales, enhancement areas, open spaces, etc.

d. Safety ledges in ponds shall be planted with native wetland species.

e. Cover Crop: Specify non-invasive species compatible with establishment of native plantings.

f. Native Seed Mixes: Nursery providing seed mix must be from within 150-200 miles of the proposed seeding location.

g. Specify size of plugs or container plants to be used.

h. Trees shall have a minimum size of 2.5” caliper diameter at breast height (approximately 5’ from the base of the tree). Specify whether trees are in containers, bare root, or balled and burlapped. A design detail for herbivory protection measures should be provided on the landscape plans.

i. Shrubs shall have a minimum size of 30 inches in height. Specify whether shrubs are in containers, bare root, or balled and burlapped.

j. Specify erosion control measures for seeding and planting.

k. Specify protection measures for trees/shrubs, herbaceous plants and tubers to prevent animal predation.

Establishment Requirements.

Areas to be planted with native species shall conform to the following requirements to insure establishment.

a. Planting areas shall have at least twelve inches of clean un-compacted topsoil. Subsoil shall be loosened and topsoil applied to minimize compaction.

b. Cover crop may be planted immediately after grading to prevent erosion if conditions are not conducive for native species seeding. Permanent native species shall be planted during the first available growing season at the appropriate time and conditions for such plantings.

c. Open areas within three (3) feet of adjacent properties already maintained in turf grass shall be regularly mowed and/or a open rail fence or similar barrier with appropriate signage shall be installed to serve as a physical separation between native plantings and adjacent properties.

d. Paths within the native landscape area shall be no more than five (5) feet in width and shall not be asphalt or oiled granular materials. Trails shall be setback to a minimum distance of 10% of the required vegetated width, leaving the remaining footage to consist of native vegetation only.

e. Trees and shrubs shall not interfere with access easements and access to stormwater basins for maintenance purposes.

Compliance & Final Acceptance of Planting.

a. The Applicant/Developer/Owner shall notify the County upon completion of plantings. The Developer/Owner's Environmental Specialist shall inspect the plantings and provide the County with a copy of the planting locations, species, and quantities for verification by the County.

b. The Applicant/Developer/Owner's Environmental Specialist shall inspect the stormwater basin plantings at least twice per year during the three-year term of the Establishment and Maintenance Cash Bond or Letter of Credit, to determine compliance with the minimum annual performance criteria. A monitoring report will be provided to the County by January 31st following each inspection.

c. The Applicant/Developer/Owner's Environmental Specialist shall inspect the plantings upon completion of all maintenance procedures and notify the County of the remedial actions taken.

d. Plantings shall meet the following minimum annual performance criteria. Areas which do not meet annual establishment standards as determined by the County shall be replanted at developer's/owner's expense.

    1) First full growing season: 90% of cover crop established. No bare areas greater than two (2) square feet. At least 25% of vegetation cover/coverage shall be native, non-invasive species. Invasive species control measures approved in the plan.

2) Second full growing season: Full vegetative cover. At least 50% of vegetation cover/coverage shall be native, non-invasive species. Invasive species control measures approved in the plan.
3) Third full growing season: At least 75% of vegetation cover/coverage shall be native, non-invasive species. Non-native species shall constitute no more than 25% relative aerial coverage of the planted area. Invasive species control measures approved in the plan.

e. Invasive and non-native species, and non-native woody plant species not specified as part of the planting plan, shall be controlled by appropriate management practices of the approved plan. None of the three most dominant species may be non-native or invasive or constitute greater than 25% aerial coverage (individually or cumulatively) by the end of the third growing season. Invasive species for the purposes of this manual shall include, but not be limited too, the following:

Ambrosia artemisiifolia & trifida Common & Giant Ragweed
Cirsium arvense Canada Thistle
Dipsacus laciniatus Cut-leaved Teasel
Dipsacus sylvestris Common Teasel
Lythrum salicaria Purple Loosestrife
Melilotus sp. Sweet Clover
Phalaris arundinacea Reed Canary Grass
Phragmides australis Giant Reed
Polygonum cuspidatum (Fallopia japonica) Japanese Knotweed
Rhamnus cathardica & frangula Common & Glossy Buckthorn (when managed in association with a planting, restoration, or enhancement plan)

f. A final compliance report and Long-Term Operation and Maintenance Plan shall be submitted by the Developer/Owner’s Environmental Specialist no less than 60 days prior to the expiration of the landscape Cash Bond or Letter of Credit, certifying that the planting meets the performance criteria and requesting the release of the landscape security. Final acceptance and release shall be determined by the County upon inspection of the site to verify compliance.

g. Should the performance criteria not be met within the allotted time, the County shall require that the area be replanted and/or a remedial action plan be submitted for approval at developer’s/owner’s expense. An extension to the landscape Cash Bond or Letter of Credit will be required for a period of at least one year. A revised compliance report shall be submitted by the developer/owner’s Environmental Specialist with follow-up inspection by the County, which shall demonstrate compliance with the performance criteria as a condition of release of the landscape Cash Bond or Letter of Credit.

Long Term Maintenance.

The Long-Term Operation and Maintenance Plan should be provided to the Home Owners Association, owner, or facilities manager. Best Management Practices shall be maintained according to approved management practices as provided for in subdivision covenants or easements, following final acceptance of the installation by the County.

a. Prescribed burning every other year, or at least every three years, is the best management method for established native prairie plantings. Burning requires a permit from Illinois EPA and notification of the local fire district. Burning shall be performed by a contractor with prior prescribed burn experience.

b. Late winter/early spring mowing to a height of six to twelve inches, with removal of hay, may be performed in alternate years where burning is not practical or conditions are not conducive to burning.

c. Application of herbicide to control invasive species may be necessary if burning does not control or eliminate them. A certified and licensed pesticide applicator shall select herbicide, which is non-toxic to animal and aquatic life, and shall apply the herbicide by the appropriate method, to prevent killing of desirable native species.

d. A schedule for inspection and removal of sediments deposited in the installed Best Management Practices is required.

APPENDIX 4.5

SOIL DESCRIPTIONS AND MANAGEMENT REQUIREMENTS

SOIL GROUPS

The soil survey of DuPage County identifies the Hydrologic Soil Group for each soil found within the County. The soil survey and/or an on-site soil classification may be used to determine the type of soil present. The four hydrologic soil groups are (SCS 1979):

- Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.
- Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.
- Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.
- Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

SOIL MANAGEMENT PLAN

- During construction, proper sediment and erosion control techniques must be observed to prevent sediment from leaving the site.
- Heavy equipment should not be allowed to travel across the area being considered for native plantings or infiltration practices. The weight will compact the soils and hinder the infiltration capabilities of the soil.
- All excavation and replacement work shall be executed during dry weather. Measurements should be taken to minimize over working and compaction of placed soil (i.e. low compression equipment, etc.).
- Soils placed within detention basins shall be placed beginning at low points and then filling outward toward the perimeter.
- Prior to placement of the topsoil the subsoil shall be scarified to a minimum depth of 6in.
- All planting areas shall have at least twelve inches of clean un-compacted topsoil.
- Final grade is expected to conform, after natural compaction, to elevations and contours delineated on the grading plan.
- Graded portions of the planting areas that do not expose suitable planting mediums shall be over excavated and re-spread with 12in of topsoil.
- All clumps, stones, and debris shall be removed and disposed of legally off-site.
- Prior to seeding the soil surface shall be rough raked to enhance retention of surface water.
- A 100% biodegradable soil erosion control blanket shall be used throughout stormwater detention areas and disturbed areas immediately after project completion to prevent erosion.

APPENDIX 4.6

PERMEABLE PAVER WORKSHEETS

ICPI TECH SPEC NUMBER · 4

Structural Design of Interlocking Concrete Pavement for Roads and Parking Lots

When considering design and construction, three types of interlock must be achieved: vertical, rotational and horizontal interlock.

Structural Design Procedure

The load distribution and failure modes of flexible asphalt and interlocking concrete pavement are very similar: permanent deformation from repetitive loads. Since failure modes are similar, a simplified procedure of the method is adapted from Reference 4 and the American Association of State Highway and Transportation Officials (AASHTO) 1986 and 1993 *Guide for Design of Pavement Structures (5)*. The following structural design procedure is for roads and parking lots. Base design for crosswalks should consider using stabilized aggregate or cast-in-place concrete. Stiffer bases will compensate for stress concentration on the subgrade and base where the pavers meet adjoining pavement materials. Design for heavy duty pavements such as port and airport pavements is covered in ICPI manuals entitled, ***Port and Industrial Pavement Design for Concrete Pavers***, and ***Airfield Pavement Design with Concrete Pavers***.

Design Considerations

The evaluation of four factors and their interactive effects will determine the final pavement thickness and material. These include environment, traffic, subgrade soil strength, and pavement materials. The design engineer selects values representing attributes of these factors. The values can be very approximate correlations and qualitative assumptions. Each factor, however, can be measured accurately with detailed engineering studies and extensive laboratory testing. As more detailed information is obtained about each factor, the reliability of the design will increase. The effort and cost in obtaining information about each should be consistent with the importance of the pavement. A major thoroughfare should receive more analysis of the soil subgrade and traffic mix than a residential street. Furthermore, the degree of analysis and engineering should increase as the subgrade strength decreases and as the anticipated traffic level increases. In other words, pavements for high volume traffic over weak soils should have the highest degree of analysis of each factor as is practical.

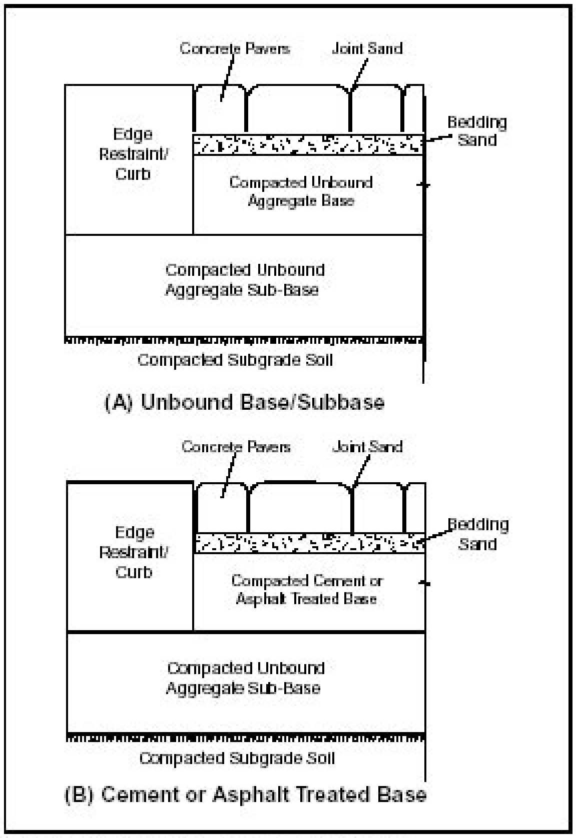

Figure 4. Typical schematic cross sections.

Environment-Moisture and temperature significantly affect pavement. As moisture in the soil or base increases, the load bearing capacity of the soil or the strength of the base decreases. Moisture causes differential heaving and swelling of certain soils, as well. Temperature can affect the load bearing capacity of pavements, particularly asphalt stabilized layers. The combined effect of freezing temperatures and moisture can lead to two detrimental effects. First, expansion of the water during freezing can cause the pavement to heave. Second, the strength of the pavement materials can be reduced by thawing. These detrimental effects can be reduced or eliminated one of three ways. Moisture can be kept from entering the pavement base and soil. Moisture can be removed before it has a chance to weaken the pavement. Pavement materials can be used to resist moisture and movement from swelling or frost. Limited construction budgets often do not allow complete protection against the effects of moisture and freeze-thaw. Consequently, their effects should be mitigated to the highest extent allowed by the available budget and materials. In this design procedure, the effects of moisture and frost are part of characterizing of the strength of subgrade soil and pavement materials. Subjective descriptions of drainage quality and moisture conditions influence design strength values for subgrade soils and unbound granular materials. In addition, if freeze-thaw exists, then soil subgrade strength is reduced according to the degree of its frost susceptibility.

Traffic-When pavement is trafficked, it receives wear or damage. The amount of damage depends on the weight of the vehicles and the number of expected passes over a given period of time. The period of time, or design life, is usually 20 years. Predicted traffic over the life of the pavement is an estimate of various vehicle loads, axle and wheel configurations, and the number of loads. The actual amount of traffic loads can often exceed the predicted loads. Therefore, engineering judgement is required in estimating expected sources of traffic and loads well into the future. Damage to pavement results from a multitude of axle loads from cars, vans, light trucks, buses and tractor-trailers. In order to more easily predict the damage, all of the various axle loads are expressed as damage from an equivalent standard axle load. In other words, the combined damaging effects of various axle loads are equated to the damaging effect of 18-kip (80 kN) equivalent single axle load (ESALs or EALs) repetitions. Damage factors for other axle loads are shown in Table 1. For example, the table shows that a single axle load of 38-kip (169 kN) would cause the same pavement damage as approximately 30 passes of an 18-kip (80 kN) single axle. For pavements carrying many different kinds of vehicles, greater study is needed to obtain the expected distribution of axle loads within the design period. If no detailed traffic information is available, Table 2 can be used for general guidance by listing typical EALs as a function of road class. EALs in Table 2 can be converted to TI or Traffic Index used by Caltrans in California to characterize axle loads. The following formula converts 18-kip (80kN) equivalent single axle loads (ESALs) to a TI: TI = 9.0 x (ESAL/10 6) 0.119 **.** Table 7 correlates ESALs used in Figures 5, 6 and 7 to TIs. In some situations, the designer cannot know the expected traffic in five, ten or fifteen years into the future. Therefore, the reliability (degree of conservatism) of the engineer's predictions can be modified as follows: Adjusted EALs = F R x EALs (estimated or from Table 2) where F R is the reliability factor. Recommended reliability factors by road class are also given in Table 2, along with the corresponding adjusted EALs and TIs for use in the design. In some residential development projects, interlocking concrete pavement streets are constructed first and then housing is built. Axle loads from construction-related truck traffic should be factored into the base thickness design. The loads can be substantial compared to the lighter loads from automobiles after construction is complete.

TABLE 1
Axle Load Damage Factors

Single Axle Kips (kN)	Single Axle Damage Factor	Tandem Axle Kips (kN)	Tandem Axle Damage Factor
2 (9)	0.0002	10 (44)	0.01
6 (27)	0.01	14 (62)	0.03
10 (44)	0.08	18 (80)	0.08
14 (62)	0.34	22 (98)	0.17
18 (80)	1.00	26 (115)	0.34
22 (98)	2.44	30 (133)	0.63
26 (115)	5.21	34 (157)	1.07
30 (133)	10.03	38 (169)	1.75
34 (157)	17.87	42 (186)	2.75
38 (169)	29.95	46 (204)	4.11

TABLE 2
Typical Design EALs

Road Class	EALs* (millions)	Reliability Factor	Design EALs* (millions)
Arterial or Major Streets			
Urban	7.5	3.775	28.4
Rural	3.6	2.929	10.6
Major Collectors			
Urban	2.8	2.929	8.3
Rural	1.5	2.390	3.5
Minor Collectors			
Urban	1.3	2.390	3.0
Rural	0.55	2.390	1.3
Commercial/Multi-Family Locals			
Urban	0.43	2.010	0.84
Rural	0.28	2.010	0.54

**Assume a 20 year design life.*

Soil Subgrade Support - The strength of the soil subgrade has the greatest effect on determining the total thickness of the interlocking concrete pavement. When feasible, resilient modulus (M r), R-value, or soaked California Bearing Ratio (CBR) laboratory tests should be conducted on the typical subgrade soil to evaluate its strength. These tests should be conducted at the most probable field conditions of density and moisture that will be anticipated during the design life of the pavement. M r tests are described in AASHTO T-307 (7); R-value in ASTM D 2844 (6) or AASHTO T-190 (7); and CBR in ASTM D 1883 (6) or AASHTO T-193 (7). CBR and R-values are correlated in Reference 9. In the absence of laboratory tests, typical resilient modulus (M r) values have been assigned to each soil type defined in the United Soil Classification System (USCS), per ASTM D 2487 (6), or AASHTO soil classification systems (see Tables 3 and 4). Three modulus values are provided for each USCS or AASHTO soil type, depending on the anticipated environmental and drainage conditions at the site. Table 3 includes formulas that explain the approximate relationship between Mr and CBR, plus Mr and R-value from Reference 9. Guidelines for selecting the appropriate M r value are summarized in Table 5. Each soil type in Tables 3 and 4 has also been assigned a reduced M r value (far right column) for use only when frost action is a design consideration. Compaction of the subgrade soil during construction should be at least 98% of AASHTO T-99 or ASTM D 698 for cohesive (clay) soils and at least 98% of AASHTO T-180 or ASTM D 1557 for cohesionless (sandy and gravelly) soils. The higher compaction standards described in T-180 or D 1557 are preferred. The effective depth of compaction for all cases should be at least the top 12 inches (300 mm). Soils having an M r of 4,500 psi (31 MPa) or less (CBR 3% or less/R-value 8 or less) should be evaluated for either replacement with a material with higher bearing strength, installation of an aggregate subbase capping layer, improvement by stabilization, or use of geotextiles.

Pavement Materials-The type, strength and thickness of all available paving materials should be established. Crushed aggregate bases, or stabilized bases used in highway construction are generally suitable for interlocking concrete pavement. Most states, provinces and municipalities have material and construction standards for these bases. If none are available, then the standards for aggregate bases found in ASTM D 2940 (6) may be used. Minimum recommended strength requirements for unbound aggregate bases should be CBR = 80% and CBR = 30% for subbases. For unbound aggregate base material, the Plasticity Index should be no greater than 6; the Liquid Limit limited to 25; and compaction should be at least 98% of AASHTO T-180 density. For unbound granular subbase material, the material should have a Plasticity Index less than 10, a Liquid Limit less than 25, and compaction requirements should be at least 98% of AASHTO T-180 density. In-place density should be checked in the field as this is critical to the performance of the pavement. If an asphalt-treated base is used, the material should conform to dense graded, well compacted, asphalt concrete specifications, i.e., Marshall stability of at least 1800 pounds (8000 N). For example, a state Superpave intermediate binder course mix required for interstate or primary roads may be adequate. Cement-treated base material should have a 7-day unconfined compressive strength of at least 650 psi (4.5 MPa). Recommended minimum base thicknesses are 4 in. (100 mm) for all unbound aggregate layers, 3 in. (75 mm) for asphalt-treated bases, and 4 in. (100 mm) for cement-treated bases. A minimum thickness of aggregate base (CBR=80) should be 4 in.

(100 mm) for traffic levels below 500,000 EALs and 6 in. (150 mm) for EALs over 500,000. Bedding sand thickness should be consistent throughout the pavement and not exceed 1.5 in. (40 mm) after compaction. A thicker sand layer will not provide stability. Very thin sand layers (less than 3 / 4 in. [20 mm] after compaction) may not produce the locking up action obtained by sand migration upward into the joints during the initial compaction in construction. The bedding layer should conform to the gradation in ASTM C 33 (6), as shown in Table 6. Do not use screenings or stone dust. The sand should be as hard as practically available.

TABLE 3
Subgrade Resilient Modulus (M_r) as a Function of USCS Soil Type
10^3 psi = 6.94 MPa

USCS Soil Group	Resilient Modulus (10^3 psi) Drainage Option 1	Drainage Option 2	Drainage Option 3	Reduced Modulus* (10^3 psi)
GW, GP, SW, SP	20.0	20.0	20.0	N/A
GW-GM, GW-GC, GP-GM, GP-GC	20.0	20.0	20.0	12.0
GM, GM-GC, GC	20.0	20.0	20.0	4.5
SW-SM, SW-SC, SP-SM	20.0	20.0	20.0	9.0
SP-SC	17.5	20.0	20.0	9.0
SM, SM-SC	20.0	20.0	20.0	4.5
SC	15.0	20.0	20.0	4.5
ML, ML-CL, CL	7.5	15.0	20.0	4.5
MH	6.0	9.0	12.0	4.5
CH	4.5	6.0	7.5	4.5

NOTE: Refer to Table 5 for selection of appropriate option.

**Use only when frost action is a design consideration.*

M_r = Resilient Modulus, psi
M_r = 1500 (CBR) Note: CBR ≤ 20%
M_r = 1000 + 555R

TABLE 4
Subgrade Resilient Modulus (M_r) as a Function of AASHTO Soil Type
10^3 psi=6.94 MPa

AASHTO Soil Group	Resilient Modulus (10^3 psi) Option 1	Option 2	Option 3	Reduced Modulus* (10^3 psi)
A-1-a	20.0	20.0	20.0	N/A
A-1-b	20.0	20.0	20.0	12.0
A-2-4,A-2-5,A-2-7	20.0	20.0	20.0	4.5
A-2-6	7.5	15.0	20.0	4.5
A-3	15.0	20.0	20.0	9.0
A-4	7.5	15.0	20.0	4.5
A-5	4.5	6.0	9.0	4.5
A-6	4.5	10.5	20.0	4.5
A-7-5	4.5	6.0	7.5	4.5
A-7-6	7.5	15.0	20.0	4.5

**Use only when frost action is a design consideration.*

Joint sand provides vertical interlock and shear transfer of loads. It can be slightly finer than the bedding sand. Gradation for this material can have a maximum 100% passing the No. 16 sieve (1.18 mm) and no more than 10% passing the No. 200 sieve (0.075 mm). Bedding sand may be used for joint sand. Additional effort in filling the joints during compaction may be required due to its coarser gradation. See ICPI Tech Spec 9, Guide Specification for the Construction of Interlocking Concrete Pavement for additional information on gradation of bedding and joint sand. Concrete pavers should conform to the ASTM C 936 (6) in the U.S. or CSA A231.2 (8) in Canada. A minimum paver thickness of 3.15 inches (80 mm) is recommended for all pavements subject to vehicular traffic, excluding residential driveways. As previously mentioned, the units should be placed in a herringbone pattern. No less than one-third of a cut paver should be exposed to tire traffic. Research in the United States and overseas has shown that the combined paver and sand layers stiffen as they are exposed to greater numbers of traffic loads. The progressive stiffening, or "lock up," generally occurs early in the life of the pavement, before 10,000 EALs. Once this number of loads has been applied, M r = 450,000 psi (3100 MPa) for the 3.125 in. (80 mm) thick paver and 1 in. (25 mm) of bedding sand. Pavement stiffening and stabilizing can be accelerated by static proof-rolling with an 810 ton (810 T) rubber tired roller. The above modulus is similar to that of an equivalent thickness of asphalt. The 3.125 in. (80 mm) thick pavers and 1 in. (25 mm) thick bedding sand have an AASHTO layer coefficient at least equal to the same thickness of asphalt, i.e., 0.44 per inch (25 mm). Unlike asphalt, the modulus of concrete pavers will not substantially decrease as temperature increases, nor will they become brittle in cold climates. They can withstand loads without distress and deterioration in temperature extremes.

TABLE 5
Environment and Drainage Options for Subgrade Characterization

Quality of Drainage	Percent of Time Pavement is Exposed to Moisture Levels Approaching Saturation			
	<1%	1 to 5%	5 to 25%	>25%
Excellent	3	3	3	2
Good	3	3	2	2
Fair	3	2	2	1
Poor	2	2	1	1
Very Poor	2	1	1	1

TABLE 6
ASTM C 33
Gradation for Bedding Sand

Sieve Size	Percent Passing
3/8 inches (9.5 mm)	100
No. 4 (4.75 mm)	95-100
No. 8 (2.36 mm)	80-100
No. 16 (1.18 mm)	50-85
No. 30 (0.600 mm)	25-60
No. 50 (0.300 mm)	10-30
No. 100 (0.150 mm)	2-10
No. 200 (0.075 mm)	0-1

TABLE 7

ESALs	TI
$5x10^4$	6
$1x10^5$	6.8
$3x10^5$	7.2
$5x10^5$	8.3
$7x10^5$	8.6
$1x10^6$	9
$3x10^6$	10.3
$5x10^6$	10.9
$7x10^6$	11.3
$1x10^7$	11.8
$2x10^7$	12.8
$3x10^7$	13.5

Structural Design Curves

Figures 5, 6, and 7 are the base thickness design curves for unbound aggregate, asphalt-treated and cement-treated materials. The thicknesses on the charts are a function of the subgrade strength (M r , Rvalue or CBR) and design traffic repetitions (EALs). Use the following steps to determine a pavement thickness:

1. Compute design EALs or convert computed TIs to EALs. Use known traffic values or use the recommended default values given in Table 2. EALs are typically estimated over a 20-year life. Annual growth of EALs over the life of the pavement should be considered.

2. Characterize subgrade strength from laboratory test data. If there is no laboratory or field test data, use Tables 3 and 4 to estimate M r , CBR or R-value.
3. Determine the required base thickness. Use M r , R-value or CBR for subgrade strength and design EALs or TIs listed in Table 7 input into Figures 5, 6 or 7, depending on the base material required. A portion or all of the estimated base thickness exceeding the minimum thickness requirements can be substituted by a lower quality, unbound aggregate subbase layer. This is accomplished through the use of layer equivalency values: 1 in. (25 mm) of aggregate base is equivalent to 1.75 in. (45 mm) of unbound aggregate subbase material; 1 in. (25 mm) of asphalt-treated base is equivalent to 3.4 in. (85 mm) of unbound aggregate subbase material; and 1 in. (25 mm) of cement-treated base is equivalent to 2.5 in. (65 mm) of unbound aggregate subbase.

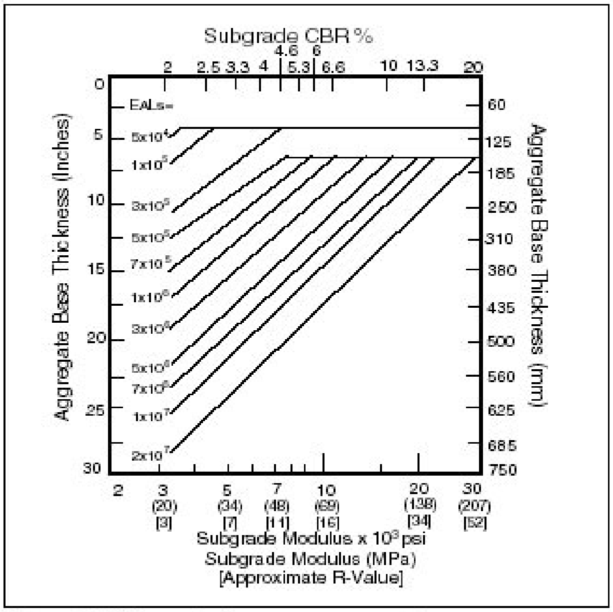

Figure 5. Thickness design curves–aggregate base.

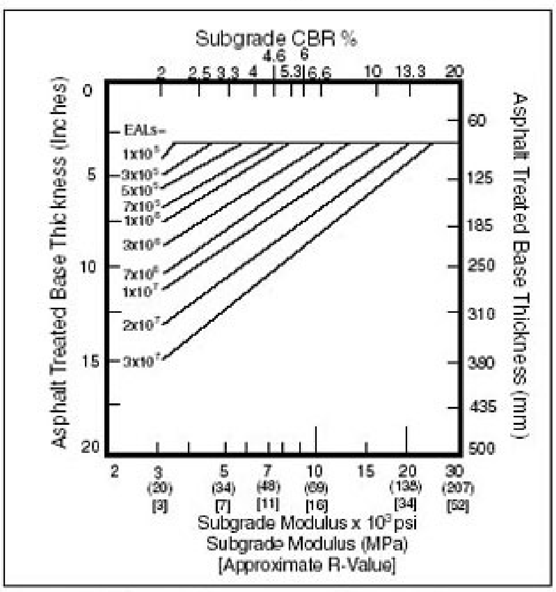

Figure 6. Thickness design curves–asphalt treated base.

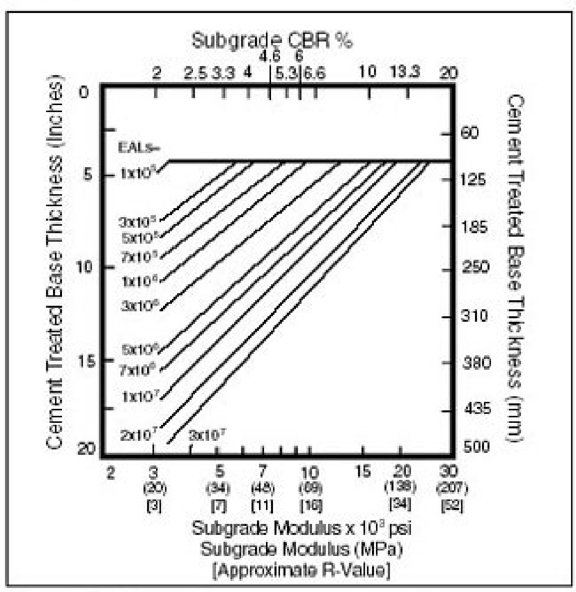

Figure 7. Thickness design curves–cement treated base.

Example

Design Data-A two-lane urban, residential street is to be designed using concrete pavers. Laboratory tests on the subgrade soil indicate that the pavement is to be constructed on a sandy silt; i.e., ML soil type according to the USCS classification system. No field CBR or resilient modulus data are available. From available climatic data, and subgrade soil type, it is anticipated that the pavement will be exposed to moisture levels approaching saturation more than 25% of the time. Drainage quality will be fair, and frost is a design consideration. Detailed EAL traffic data are not available. Using the above information, designs are to be developed for the following base and subbase paving materials: unbound aggregate base, asphalt-treated base, and unbound aggregate subbase. All designs are to include a base layer but not necessarily the aggregate subbase layer.

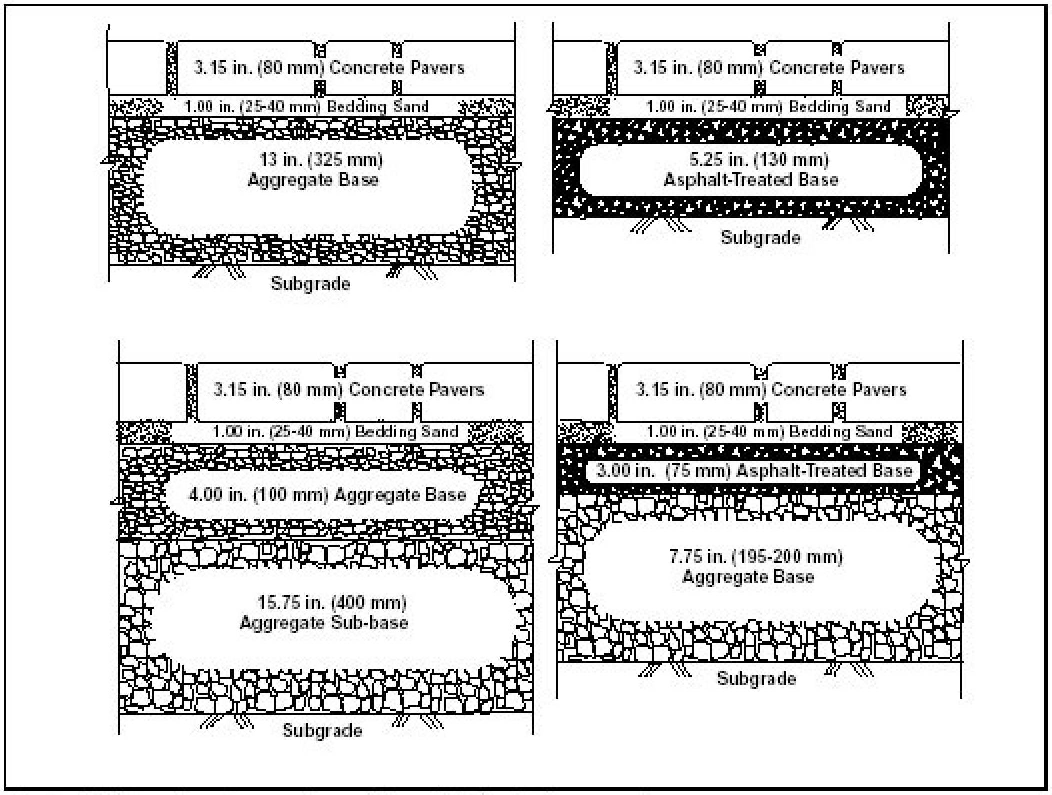

Figure 8. Alternative cross section solutions for the design example.

Solution and Results

1. Estimate design EAL repetitions. Since detailed traffic information was not available, the value recommended in Table 2 was used: 840,000 design EALs or TI = 8.8.
2. Characterize subgrade soil strength. Since only its USCS soil classification is known, Table 3 was used to establish the design strength value. For a USCS ML soil and the given moisture and drainage conditions, the estimated subgrade modulus value is M r = 7,500 psi (52 MPa), CBR = 5% or R-value = 23. Since frost action is a consideration, the reduced design strength value is M r = 4,500 psi (31 MPa), CBR = 3% or R-value = 8.
3. Determine base thickness requirements. Input of the design traffic (840,000 EALs) and subgrade strength (M r = 4,500 psi [31 MPa]) values into Figures 5 and 6 yields base thickness requirements of 13 in. (330 mm) for unbound aggregate, or 5.25 in. (133 mm) for an asphalt treated base. These values can be used to develop subbase thicknesses.

Since all designs must include a base layer, only that thickness exceeding the minimum allowable value, 4 in. (100 mm) for aggregate bases and 3 in. (75 mm) for asphalt-treated bases, was converted into subbase quality material. With the aggregate base option, 9 in. (230 mm) or 13 4 in. of material can be converted into aggregate subbase quality material, resulting in 15.75 inches (400 mm) or 9 x 1.75 inches. Likewise, for the asphalt-treated base option, 2.25 in. (57 mm) or 5.25 3.0 in. of material can be converted into aggregate subbase quality material, resulting in 7.75 in. (197 mm) or 2.25 x 3.40 in. The final cross section design alternatives are shown in Figure 8 with 3.15 in. (80 mm) thick concrete pavers and a 1.0 in. (25 mm) thick bedding sand layer over several bases. These are a sample of the possible material type and thickness combinations which satisfy the design requirements. Cost analyses of these and other pavement cross section alternatives should be conducted in order to select the optimal design.

Computerized Solutions

Interlocking concrete pavement can be designed with ICPI Lockpave software, a computer program for calculating pavement base thicknesses for parking lot, street, industrial, and port applications. User designated inputs include traffic loads, soils, drainage, environmental conditions, and a variety of ways for characterizing the strength of pavement materials. Parking lot and street pavement thickness can be calculated using the 1993 AASHTO pavement design procedure (an empirical design method) or a mechanistic, layered elastic analysis that computes projected stresses and strains in the pavement structure modified by empirical factors. The AASHTO 2002 Guide for Design of Pavement Structures includes procedures for mechanistic analysis of pavement layers. Outputs include pavement thickness using different combinations of unstabilized and stabilized bases/subbases. Base thicknesses can be calculated for new construction and for rehabilitated asphalt streets using an overlay of concrete pavers. After a pavement structure has been designed, the user can project life-cycle costs by defining initial and lifetime (maintenance and rehabilitation) cost estimates. Design options with initial and maintenance costs plus discount rates can be examined for selection of an optimal design from a budget standpoint. Sensitivity analysis can be conducted on key cost variables on various base designs. For further information on ICPI Lockpave, contact ICPI members, ICPI offices, or visit the web site http://www.icpi.org.

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APPENDIX 4.7

COST COMPARISON
SPECIFIC TO LAKE COUNTY FOREST PRESERVES

This is a very preliminary figure based upon conceptual designs; no engineering design has been completed to date:

40,000 SF - Uni-Lock Eco-Loc Pavers – 25 years

Item	Frequency	Cost	
Installation	1 x	165,350.00	Pavers, 24” & 12” base, drain tile, excavating, hauling
		**15,000.00	Detention – excavating, hauling, topsoil, seeding, pipe
Vacuum sweep	As needed~2x per yr	0	Cooperative Agreement – Lake County DOT has Johnston vacuum sweeper
Restore permeability	1x per 4-5 yrs or as needed	1750	350.00 each @ 5 Service contract @ 82.00/hr. – vacuum & remove void aggregate. The District cleans, and replaces. *
Refresh base	1x per 25 yrs	8100	Replace base/drain as needed (reuse pavers)
Total Life-cycle cost over 25 years:		190,200	

**Assumption of cleaning and replacing with same aggregate.*
*** Preliminary calculation. Based upon total detention requirement - % porosity of base.*

40,000 SF - Asphalt Parking Lot - LCFP costs – 25 years

Item	Frequency	Cost	
Installation	1 x	109,000.00	1x 3” asphalt, 12” base, striping, excavating, hauling
		25,000.00	Detention – excavating, hauling, topsoil, seeding, pipe
Crack Sealing	1 x per yr	6250	250.00 / yr @ 25 x
Seal Coat	1 x per 5 yrs	100,000.00	20,000.00 / 5 yrs @ 5 x
Striping	1 x per 5 yrs	3125	625.00 @ 5x 6.00 / space 12.00 / HC space 96 spaces w/4 HC
Patching	As needed	500	1x / 5 yrs @ 100.00/patch
Replace paving surface	1 x per 20 yrs	32,000.00	1x Asphalt surface and striping
Total Life-cycle cost over 25 years:		275,875	

Permeable Paver Research Summary (Lake County Forest Preserves, February 2003)

GLOSSARY OF ACRONYMS

BMP- Best Management Practice.

BOD- Biological oxygen demand.

CWA- Clean Water Act.

DCSFPO- DuPage County Stormwater and Flood Plain Ordinance.

DO- Dissolved Oxygen.

MS4- Municipal Separate Storm Sewer System.

NOI- Notice of Intent

NPDES- National Pollutant Discharge Elimination System.

NURP- National Urban Runoff Program

SWPP- Stormwater Pollution Prevention Plan.

TDS- Total dissolved solids.

TMDL- Total daily maximum load.

TSS- Total suspended solids.