



# Selecting Stormwater BMPs – Identifying The Best Options



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March 2011  
2011RIC01PP



# Presentation Outline

- Project Background and Need
- Stormwater Best Management Practices Utilized
- Decision Tree 5-Step Process
- Conclusions
- Resources

Step 1 – Select Your Project Type



Step 2 – Describe Your Project



Step 3 – Determine the Regulatory Environment for Your Project



Step 4 – Create a Preliminary BMP Toolbox



Step 5 – Refine BMP Selection/Select the Right "Tool"



LRRB Selecting Stormwater BMPs



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- Development of new initiatives,
- Acquisition of and application of new knowledge, and
- Exploration and implementation of new technologies.



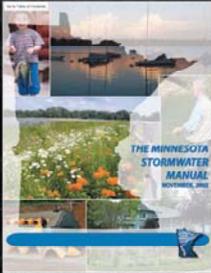
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# Project Goals

- Provide a scoping-level tool to assist in the selection of best management practices (BMPs) appropriate for specific projects.
  - A Decision Tree for Stormwater BMPs
- Work in conjunction with Minnesota Stormwater Manual and Stormwater Maintenance BMP Resource Guide (LRRB 2009RIC12)



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Intended users:

- City and County public works
- Young engineers
- Developers
- Public officials and other non-engineers

The Decision Tree distills information from many manuals and sources into one spot, and provides convenient documentation for how/why decisions are made on a project-by-project basis.

Intended for use with projects for which there is no regional stormwater facility available.

## Project Need

- The variety of BMP practices is increasing.
- Stormwater permit rules are becoming more stringent and performance based.
- Different BMPs perform different functions and have different removal efficiencies.
- Frequency and intensity of maintenance can vary greatly between BMP types.

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BMP functions that may be required:

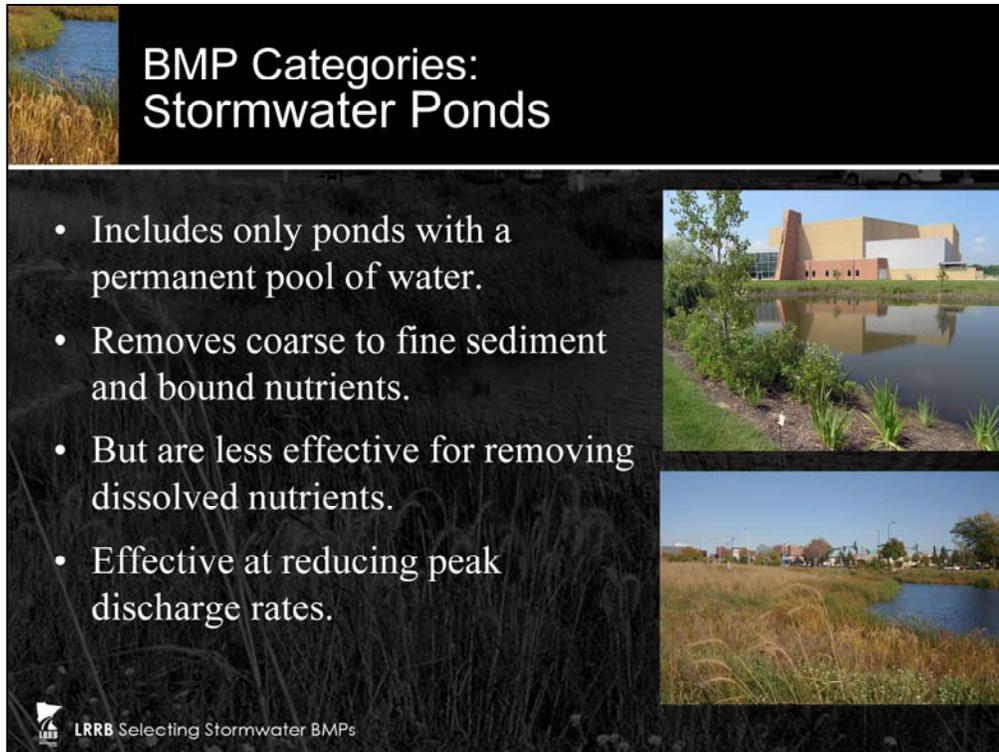
- Sediment control
- Nutrient removal
- Volume reduction
- Peak discharge rate control
- Channel protection



# BMP Categories

- Primary Focus: BMPs that are commonly used in Minnesota
  - Stormwater Ponds
  - Bioretention Facilities
  - Underground Treatment Devices
  - Underground Detention
  - Infiltration
  - Porous/Pervious/Permeable Pavements
  - Tree or Planter Box





## BMP Categories: Stormwater Ponds

- Includes only ponds with a permanent pool of water.
- Removes coarse to fine sediment and bound nutrients.
- But are less effective for removing dissolved nutrients.
- Effective at reducing peak discharge rates.

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Stormwater ponds are typically installed as an end-of-pipe BMP at the downstream end of a trunk storm sewer system or of a treatment train.

Wet extended detention basins are the only type of pond that complies with the NPDES Permit.

- Dry detention ponds are ones in which the outlet elevation matches or is slightly below that of the inlet elevation. All runoff that enters the pond is considered to leave the pond, but the outlet is restricted to temporarily store the runoff prior to discharge. There is no sediment storage, and sediment that was previously deposited often is carried downstream with larger storm events. Therefore, dry detention ponds provide rate control but no water quality benefits.

- Frequently, unlined wet detention ponds can dry out between storm events if they are constructed in sandy soil due to infiltration. These may still be considered to provide water quality benefits as the runoff has to pond up to a certain depth before it can discharge through the outlet pipe, allowing for sedimentation. Water quality benefits also seen through infiltration of the runoff.

Commonly used names: NURP ponds, multi-cell ponds with a wet forebay, retention ponds, and unlined or lined wet ponds.

Benefits:

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

Limitations:

- Relatively large space requirement
- Tends to increase water temperature and may cause downstream thermal impact
- Potential for nuisance insects or odor
- Problematic for areas of low relief, high water table, near-surface bedrock, wellhead protection areas or source water protection areas without a liner

## BMP Categories: Bioretention

- Shallow, landscaped depressions that capture and filter runoff.
- Vegetation is a key part of treatment process.
- Removes fine sediment, nutrients, trace metals & others.
- Can provide volume control.

**BIOSWALE TYPICAL SECTION**

Water height during storm

Native Plants Tolerant of Inundation

Grass filter strip (pre-treatment)

AMENDED SOIL

Perforated underdrain with filter aggregate may be required in some cases

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Commonly used names: rain gardens, bio-infiltration basins, bio-filtration basins, bioretention basins, bioswales

Current “trendy” BMP in stormwater management = rain garden

Benefits:

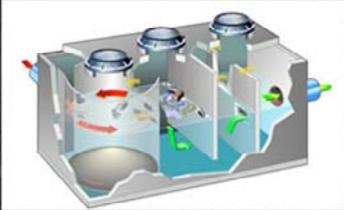
- Can be very effective for removing fine sediment, trace metals, nutrients, bacteria, and organics.
- Provides many additional environmental (habitat, improves air quality, urban micro-climates), social (creates a unique sense of place), and economic benefits (reduces development and maintenance cost, greater lot yield, increases property values).
- Well suited for high impervious areas.
- Reduces runoff volume.
- Flexible design, affording many opportunities for creativity.
- Less thermal impacts to surface waters than typical wet detention pond.

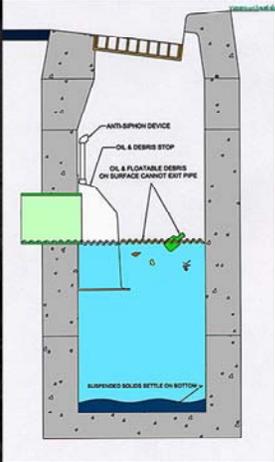
Limitations:

- Susceptible to clogging by sediment; therefore maintenance and pre-treatment is necessary to maintain effectiveness.
- May not be effective for large drainage areas (use multiple structures, closer to source of runoff).
- Soil medium prone to erosion (use energy reduction measures for incoming stormwater).

## BMP Categories: Underground Treatment Devices

- Removes coarse sediment and some oil/floatables.
- Best suited as pre-treatment for other BMPs.





LRRB Selecting Stormwater BMPs

They can take a variety of forms and use a variety of technologies or methods to provide stormwater quality treatment. Generally, they act as oil and grit separators using the physical principles of sedimentation for the grit and phase separation for the oil. They are most effective on coarse sediments and have reduced effectiveness at removing pollutants such as nutrients or metals.

Commonly used names: oil/grit separator, grit chamber, sump manhole/catch basin, wet vault, hydrodynamic separator, water quality inlet, and proprietary stormwater treatment device.

Benefits:

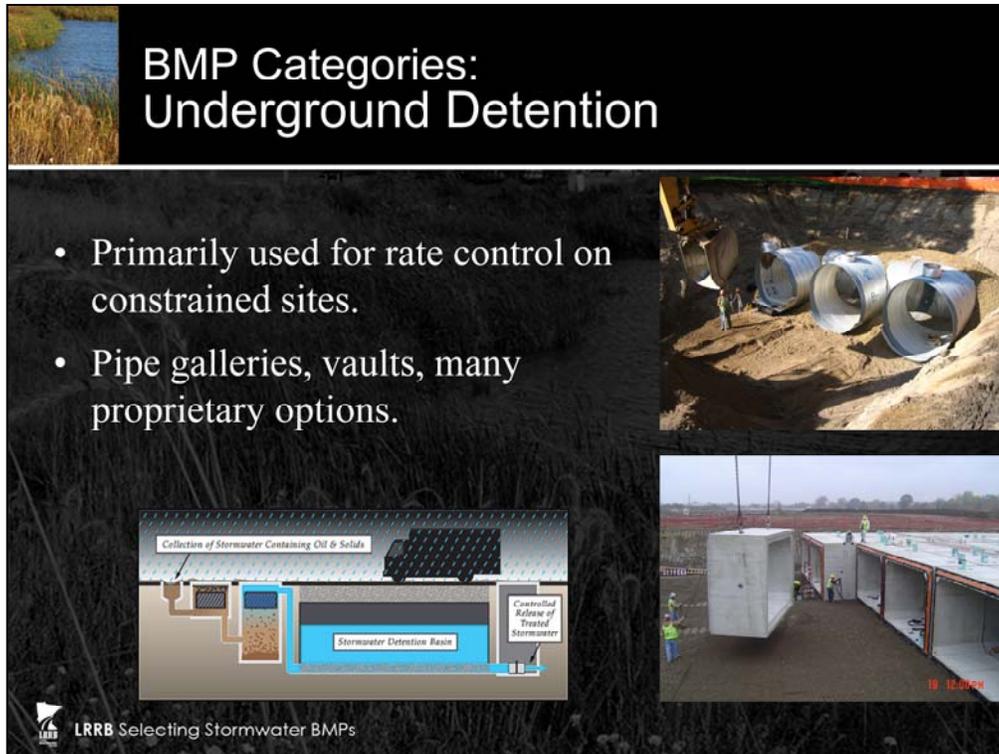
- Units are underground and do not consume much land area, which allows the land to be used for other purposes (parking lots, etc.).
- They can often be easily incorporated into fully developed sites and for retrofit of existing systems.
- They can be used for pre-treatment prior to other BMP practices.
- They can be suitable for cold climates if installed below frostline.
- Many provide an easily accessed structure for maintenance.
- Standardized designs allow for relatively easy installation.

Limitations:

- Each type of unit has specific design constraints and limitations for use.
- Treatment may be reduced if frequent maintenance is not conducted.
- They may not meet local standards when used alone.
- They are generally good for solids and litter, but much less effective for common soluble pollutants.
- These types of facilities require OSHA confined space entry procedures.

## BMP Categories: Underground Detention

- Primarily used for rate control on constrained sites.
- Pipe galleries, vaults, many proprietary options.



The composite image illustrates underground detention systems. On the left, a cross-section diagram shows a roof collecting stormwater containing oil and solids into a 'Stormwater Detention Basin'. The water is then released through a 'Controlled Release of Treated Stormwater' outlet. On the right, two photographs show the construction process: the top photo shows large concrete pipes being laid in a trench, and the bottom photo shows a completed system with several interconnected vaults.

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Underground detention devices are used to store stormwater runoff temporarily. Stored water is released directly through an outlet pipe back into various downstream conveyance systems or water bodies at rates designed to reduce peak water flows during storms to better mimic predevelopment conditions.

**These devices could provide some water quality treatment with design modifications.**

*Perforated or open bottom underground galleries that allow infiltration into the underlying soil are included in the "Infiltration" BMP category.*

#### Benefits:

- Reduces peak stormwater runoff flow rate.
- Provides extended storage and slow, measured release of collected stormwater runoff.
- Good option for high density or urban areas with limited available space, unusual shapes or where land is expensive.
- Prefabricated modular systems can be relatively quick to install.
- Durability and long life (50 years plus for most systems).

#### Limitations:

- Provides varying degrees of water quality improvement. To achieve water quality improvement additional stormwater BMPs must be incorporated in-line with storage system.
- Special equipment (and access) is often required to perform routine maintenance.
- There is the potential for noxious gases to form in the system.
- Confined space protocols may be required during inspections and maintenance.

## BMP Categories: Infiltration

- Design variants include:
  - Surface sand filters (plants do not aid in treatment)
  - Infiltration trenches
  - Perforated pipe galleries
- Removes fine sediment and nutrients.
- Provides volume control.

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In general terms, infiltration systems can be described as natural or constructed depressions located in permeable soils that capture, store, and infiltrate stormwater runoff. These depressions can be located at the surface of the ground (e.g. infiltration basin) or they can be designed as underground facilities (e.g. structural chamber or excavated pit filled with aggregate such as an infiltration trench). As the stormwater penetrates the underlying soil, chemical, biological, and physical processes remove pollutants and delay or reduce peak stormwater flows.

*This section deals with structural practices relying on infiltration processes that are distinguishable from bioretention practices in that the former do not rely on vegetation to aid in the treatment.*

Benefits:

- Reduces peak stormwater runoff flow rate.
- Increases groundwater recharge.
- Improves surface water quality.
- Provides thermal benefits to cold water fisheries.

Limitations:

- Effectiveness is sensitive to construction and maintenance practices.
- Tendency to lose effectiveness over time due to clogging if not properly constructed or maintained.
- Not recommended for areas with steep slopes, karst topography, adjacent to buildings, or near potential stormwater hotspots.
- Special equipment (and access) is often required to perform routine maintenance for underground infiltration systems.
- Surface infiltration systems may require landscaping capable of handling periods of inundation and drought.
- Typically need to be paired with a pre-treatment device.

## BMP Categories: Porous/Pervious/Permeable Pavements

- Concrete, asphalt, block pavers, reinforced turf systems, amended soils
- Can be designed for infiltration or filtration.
  - Type and level of treatment changes accordingly.

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Runoff is stored in the stone aggregate base course/storage layer and allowed to infiltrate into the surrounding soil, or collected by an underdrain system and discharged to the storm sewer system or receiving waters.

### 3 Categories:

- 1) Porous Pavements – porous surfaces that infiltrate water across the entire surface (i.e. porous asphalt and pervious concrete pavements);
- 2) Permeable Pavers – impermeable modular blocks or grids separated by spaces or joints that water drains through (i.e. block pavers, plastic grids, etc.);
- 3) Amended Soils - Fiber or artificial media added to soil to maintain soil structure and prevent compaction.

### Benefits:

- Can provide groundwater recharge and reduces stormwater runoff volume.
- Can reduce peak discharge rates by diverting stormwater into the ground and away from the pipe-and-pond stormwater management system.
- Grass pavers can improve site appearance by providing vegetation in areas of low volume parking where there would otherwise be only pavement.
- Increases effective developable area on a site because portions of the stormwater management system are located underneath the paved areas.
- When designed for infiltration, can significantly reduce the need for large stormwater management structures on a site.
- The dead air and void spaces in the base course provide insulation so that the frost line is closer to the surface.

### Limitations:

- Permeable paving can be prone to clogging from sand and fine sediments that fill void spaces and the joints between pavers.
- Should be used carefully where frequent winter sanding is necessary because the sand may clog the surface of the material.
- Periodic maintenance is critical, and surfaces should be cleaned with a vacuum sweeper at least three times per year.
- In cold climates, the potential for frost heave may be a concern for the use of permeable paving. S
- Permeable paving should be used carefully when being used to receive stormwater from other drainage areas, especially any areas that are not fully stabilized.
- May not be suitable for use on steep slopes (>5%).
- May not be suitable for use in high-traffic areas or where it will be subject to heavy axle loads.
- Snow plows can catch the edge of grass pavers and some paving stones. Rollers should be attached to the bottom edge of a snowplow to prevent this problem.

# BMP Categories: Tree or Planter Box

- Very localized bioretention system.

The diagram shows a cross-section of a tree box filter. It consists of a concrete curb on the left, a concrete base, and a concrete grate. Below the grate is a layer of soil, followed by a layer of mulch, and then a layer of gravel. A tree is planted in the center. The diagram is labeled with 'A' through 'E' and includes the following text:

TREE TRUNKS CAN COLLECT WATER FROM  
ROADS AND TREES BY  
A - CURBS CONNECTED BELOW THE  
GRATE  
B - FILTER SYSTEM INTEGRATED INTO  
ARCHITECTURAL DESIGN  
C - PLANTS GUT INTO THE CURB  
DRAINAGE GRATES ALLOW RUNOFF FROM THE  
SIDEWALK INTO THE TREE BOX  
LUMEN CAN BE INSTALLED UNDER THE  
GRATE  
SOIL AND MULCH ALLOW WATER STORAGE  
AND INFILTRATION WHILE PROVIDING  
A SUPPORTIVE TREE GROWTH MEDIUM  
UNDERDRAINS CAN CONNECT TO TRADITIONAL  
DRAINAGE SYSTEMS

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Simple “tree pits” are used for local drainage interception, in which a very shallow ponding area is provided in a “dished” mulch area around the tree or shrub. Tree box filters can be used in highly urbanized streetscapes. The system consists of a container filled with a soil mixture, a mulch layer, underdrain system and a shrub or tree. Stormwater planters are self-contained landscaping areas that capture and temporarily store a fraction of rooftop runoff and filter it through the soil media.

**Benefits :**

- Can be adaptable to integration with site landscaping, and offer an aesthetically attractive opportunity to provide highly effective stormwater treatment.
- Can be used to meet recharge objectives, where underlying soils are suitable and where allowed by land use and receiving water characteristics.
- Their small scale allows volume and water quality control to be tailored to specific site characteristics and provides the ability to customize stormwater management techniques to target specific pollutants using different soil media.

**Limitations:**

- Do not use tree box filters to treat runoff from high-load areas.
- Cannot be constructed until up gradient areas are fully stabilized.
- Typically used in highly visible areas and therefore, may require frequent inspection to remove trash and tree/vegetation maintenance.



# Decision Tree for BMPs: A 5-Step Process

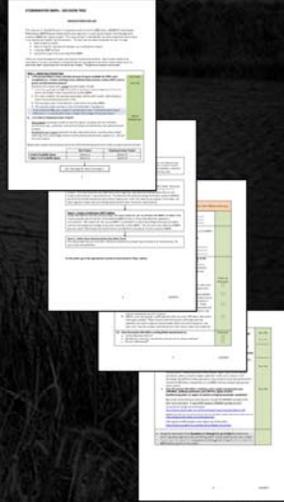
Step 1 – Select Your Project Type

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# Step 1 – Select Your Project Type

Step 1 – Select Your Project Type

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How much space will be available for BMPs?

AND

Is it a Site or Roadway/Linear Project?

See next page for Steps 2 through 5.

**STORMWATER BMPs - DECISION TREE**

INSTRUCTIONS FOR USE

This resource is intended to work in conjunction with an earlier LRRB report, 2009RAC12: Stormwater Maintenance BMP Resource Guide and to assist agencies in selecting stormwater best management practices (BMPs) for a given project. This resource tool is intended for use with projects for which there is no regional stormwater facility available. The tool has five steps that guide the user through:

- describing the project,
- determining the regulatory framework surrounding the project,
- creating a BMP toolbox,
- and performing a final screening of the BMPs.

These are recommendations based upon typical situations/conditions. Each project needs to be evaluated on its own parameters, and good engineering judgment should be used to determine if a particular BMP is applicable for the particular project. The general process is as follows:

**Step 3 – Select Your Project Type**

a. Is the project likely to have a limited amount of space available for BMPs once completed (i.e., is there not likely to be sufficient land area for surface BMPs such as ponds and bioretention basins)?

Examples of a project with limited available space include:

- Less than \_\_\_\_% (percentage to be filled in by City or County Engineer) of the area within the project limits is available for surface BMPs.
- For linear projects, the available space does not fall within public right-of-way or within the planned construction limits.
- The available space is too steep for construction of surface BMPs.
- The available space consists primarily of wetlands or floodplains.

If you answered "Yes," your project is considered to have "Limited Available Space". Otherwise, it is considered to have a "Higher Percentage of Available Space".

b. Is it a Site or Roadway/Linear Project?

Site projects encompass a wide variety of projects including, but not limited to, preliminary plans, residential, commercial/industrial/institutional, and redevelopment projects. Roadway/Linear project examples include road construction, reconstruction and/or widening, trails, and bridges that are constructed as stand-alone projects (i.e., not part of a site project).

Based upon answers to the above, go to one of the following sections to create a project-specific toolbox:

	Site Project	Roadway/Linear Project
Limited Available Space	Site-Low Avail. Space	Linear-Low Avail. Space
Higher % of Available Space	Site-High Avail. Space	Linear-High Avail. Space

See next page for Steps 2 through 5.

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STORMWATER BMPs - DECISION TREE | INSTRUCTIONS

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**Step 2 – Describe Your Project**

This step asks the user several questions in an effort to better understand the project, the downstream receiving waters, and design constraints.

**STEP 2 - DESCRIBE YOUR PROJECT**  
This will help determine which permits and types of BMPs are required and will work effectively for your project.

**2.1 Where is the project?**  
Address/location \_\_\_\_\_  
City/Township \_\_\_\_\_  
County \_\_\_\_\_

**2.2 What lake, river, or stream does it ultimately drain to?**  
Use USGS quadrangle maps, other types of contour/topographic maps, or the MPCA interactive map tool at <http://arc.gis02.pca.state.mn.us/webtools/stormwater/locviewer.htm>  
Fill in name or names of the receiving waters.  
\_\_\_\_\_  
\_\_\_\_\_

**2.3 What types of soils exist throughout the project area, and in particular at the location(s) of the potential BMP(s)?** Check A, B, C, D, or combinations of.  
Use soil boring data if available. Otherwise use County soil surveys, found at:  
• <http://webtools.rcwrp.mn.gov/WellSoilSurvey.aspx> (Interactive)  
• [http://soils.usda.gov/serms/online\\_surveys/nomessual/](http://soils.usda.gov/serms/online_surveys/nomessual/) (similar to the standard paper copies)

Standard hydrologic soil groups (HSG) are:  
 A. HSG A = sandy soils having low runoff potential with high infiltration rates even when thoroughly wetted. These consist primarily of deep, well to excessively drained sands and/or gravels.  
 B. HSG B = soils having moderate infiltration rates even when thoroughly wetted, consisting chiefly of moderately deep to deep soils that have moderately fine to moderately coarse textures. These are moderately well to well drained soils.  
 C. HSG C = soils having slow infiltration rates when thoroughly wetted. These consist primarily of soils with a layer that impedes the downward movement of water, or soils with moderately fine to fine texture and a slow infiltration rate and an occasional clay-lin in nature.  
 D. HSG D = soils having high runoff potential with very slow infiltration rates when thoroughly wetted. These consist chiefly of clay soils with high swelling potential; soils with a high permanent water table; soils with compact or clay layer at or near the surface; and shallow soils over nearly impervious materials.

**2.4 Does the project fall within a setting likely characterized as:**  
 a. Central Business District?   
 b. Residential, suburban, low-density commercial or campus settings?   
 c. Rural/ undeveloped?

Check all that apply:  
 High Infiltration Soils  
 Low Infiltration Soils  
 High Infiltration Soils  
 Low Infiltration Soils  
 Agricultural

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 STORMWATER BMPs - DECISION TREE | Site - Low Infiltration Soils  
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The answers to these questions will be used in Steps 3 and 4

Soil types may affect which BMPs will be practicable or require design modifications

Project setting – may dictate the form and aesthetics of the BMP

# Step 2 – Continued

Step 2 – Describe Your Project

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Different site considerations and design constraints can affect the type of BMP used.

<b>2.5 Are there special site considerations that could affect the BMP selection?</b> <b>a. There are no special site considerations, such as those listed in 2.5.b through 2.5.e.</b>	Yes / No	[Green Box]
<b>b. Is there soil or groundwater contamination?</b>	Yes / No	[Green Box]
<b>c. What is the depth to bedrock?</b> <small>There must be at least 3 feet of separation from the bedrock elevation to the bottom of any infiltration practice.</small>	Yes / No	[Green Box]
<b>d. What is the seasonal high groundwater elevation in the vicinity of the potential BMP?</b> <small>There must be at least 3 feet of separation from the seasonal high groundwater elevation to the bottom of any infiltration practice.</small>	Yes / No	[Green Box]
<b>e. Will the BMP receive runoff from a potential stormwater hotspot (PSH)?</b> <small>PSHs are defined as commercial, industrial, institutional, municipal, or transportation-related operations that produce higher levels of stormwater pollutants, and/or present a higher potential risk for spills, leaks or illicit discharges. Runoff from these operations may contain soluble pollutants which cannot be effectively removed by current BMPs and can compromise ground water quality.</small>	Yes / No	[Green Box]
<b>f. Does the project fall within a drinking water supply management area (DWSMA), wellhead protection zone (WHPZ), region of karst landforms/aquifers, or region of medium to high groundwater sensitivity?</b> <small>Municipal comprehensive plans typically include the DWSMA boundaries for their municipal wells. A map of Minnesota's DWSMA boundaries with vulnerability ratings can be found at <a href="http://www.health.state.mn.us/dhs/oh/water/wsm/mnmap/gis/download.pdf">http://www.health.state.mn.us/dhs/oh/water/wsm/mnmap/gis/download.pdf</a>  WHPZ boundaries can be found on the County Well Index interactive web tool at <a href="http://www.health.state.mn.us/dhs/oh/w/">http://www.health.state.mn.us/dhs/oh/w/</a>  Information on Minnesota's karst region can be found at <a href="http://www.pca.state.mn.us/water/groundwater/karst.html">http://www.pca.state.mn.us/water/groundwater/karst.html</a> </small>	Yes / No	[Green Box]
<ul style="list-style-type: none"> <li>• Using the information from Questions 2.1 through 2.4, go to Step 3 to determine which regulatory agencies have permitting and/or review authority over your project.</li> <li>• You will use information from Questions 2.3 through 2.5 in Step 4, which creates the BMP toolbox specific to the project.</li> </ul>		

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STORMWATER BMPs - DECISION TREE | Site - Low Available Space

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Special site considerations: soil/groundwater contamination, shallow groundwater/bedrock, potential stormwater hotspots, DWSMA, karst, etc.

Design constraints include topography, soils, project setting, contaminated soil or groundwater, bedrock, wellhead protection zones, and other issues that could preclude certain BMPs from being used.

# Step 3 – Determine the Regulatory Environment for Your Project

Step 3 – Determine the Regulatory Environment for Your Project

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A variety of state, local, and federal agencies regulate projects that impact Minnesota's water resources. The National Pollutant Discharge Elimination System (NPDES) permit will cover the majority of projects in the state.

**STEP 3 – DETERMINE THE REGULATORY ENVIRONMENT FOR YOUR PROJECT**

A variety of state, local, and federal agencies regulate projects that may impact Minnesota's water resources. In many cases, a permit is required from one or more of these agencies before proceeding with the project. This step starts at the broadest level, with the agency that has jurisdiction over most projects that occur within the state. The focus is then narrowed down to the local governmental units. The intent is to determine the most stringent stormwater criteria that affect your project, which will then help determine which BMPs can meet those requirements.

**3.1 Does your project require a National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) General Stormwater Permit for Construction Activity from the Minnesota Pollution Control Agency (MPCA) and/or a Stormwater Pollution Prevention Plan? (Answer questions a-c to determine.)**

- The MPCA has jurisdiction through the NPDES/SDS permit for projects over 1 acre in size or part of a larger common plan of development if less than 1 acre in size.
- The NPDES/SDS requirements will typically set the minimum stormwater criteria for all projects within the state. Other agencies may require higher levels of treatment.
- For information on the NPDES/SDS permit, application form and other information, go to <http://www.mPCA.state.mn.us/index.php/water/water-tsdps-and-programs/stormwater/construction-stormwater/construction-stormwater.html>

NPDES Permit:	NPDES Permit Required
<b>a. Will the project disturb one or more acres of land?</b> This includes clearing, grading and excavation, but does not include routine maintenance that is performed to maintain the original line and grade, hydraulic capacity or original purpose of the facility. (MPCA)	<input type="checkbox"/>
<b>b. If No, is the project part of a larger common plan of development?</b> A common plan of development or sale means a continuous area where multiple separate and distinct land-disturbing activities may be taking place at different times, on different schedules, but under one proposed plan. (MPCA) If Yes, a NPDES/SDS permit is required. Check box; then go to Question 3.1.c. If No, a NPDES/SDS permit is not required. Go to Question 3.2.	<input type="checkbox"/>
<b>Stormwater Pollution Prevention Plan (SWPPP):</b> <b>c. Will the amount of impervious surface increase over that of the existing condition as a result of the project?</b> If Yes, the following components of the SWPPP are required as part of the NPDES/SDS permit as described in Parts II, IV and Appendix A of the permit. See the permit for design criteria. (Check boxes.) Temporary Sediment Basins (Part II.B) Permanent Stormwater Management System (Part III.C) Construction Activity Requirements (Part IV)	Yes / No SWPPP Components Required <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>

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STORMWATER BMPs - DECISION TREE | Site | Low Available Space

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In many cases, a permit is required from one or more of these agencies before proceeding with the project. This step helps the user determine which agencies may have permitting authority over the project and what their requirements are.

# Step 3 – Continued

Step 3.2 – Are there other entities with regulatory authority? Which are the most stringent?

- County, city, township ordinance?  
 Watershed district or management organization rules?  
 Potential requirements:
- Rate control
  - Water Quality
  - Volume reduction
  - Channel protection
  - Antidegradation (Nondegradation)

If No, the following components of the SWPPP are required as part of the NPDES/SDS permit as described in Parts III, IV and Appendix A of the permit. See the permit for design criteria. (Check boxes.)  
 Temporary Sediment Basins (Part II.8)  
 Construction Activity Requirements (Part IV)

SWPPP Components Required

3.2 Does the county, city, or township have requirements that are MORE STRINGENT than the NPDES permit? (Answer questions a-e in the table below to determine.)

- For a listing of potential agencies and their contact information, go to: [http://www.dnr.state.nh.us/permits/water/water\\_permit\\_contacts.html](http://www.dnr.state.nh.us/permits/water/water_permit_contacts.html)
- Many counties have a Soil and Water Conservation District (SWCD) that can provide recommendations and technical information. For links to the various county SWCDs, go to: [http://www.meredith.org/SWCDs\\_On\\_The\\_Web/wscd\\_on\\_the\\_web.htm](http://www.meredith.org/SWCDs_On_The_Web/wscd_on_the_web.htm)

Contact each of the potential agencies listed and fill in their criteria for the following questions in the table below:

	County	City	Township
a. Is rate control required [y/n]?			
b. Is volume control [y/n] required?			
c. Is water quality treatment [y/n] required? If yes, what is the specified % removal required for: Total suspended solids (TSS) Total phosphorus (TP)			
d. Do the BMPs need to provide for downstream channel protection [y/n]? See definition below.			
e. Does the project need to meet an antidegradation (nondegradation) requirement to comply with a MS4 permit [y/n]? See below.			

The purpose of channel protection criteria is to prevent habitat degradation and erosion in urban streams caused by an increased frequency of bankfull and sub-bankfull stormwater flows and to minimize downstream channel enlargement and incision that is a common consequence of urbanization.

For information on what a MS4 permit is, see: <http://www.pca.state.nh.us/qaes/best/bestpracticesandprograms/stormwater/municipal-stormwater/municipal-separate-storm-sewer-systems-ms4.html#what>  
 For an interactive map of MS4 entities within the state, visit: [http://pca.pca.state.nh.us/webSite/stormwater/ms4\\_sms/viewer.htm](http://pca.pca.state.nh.us/webSite/stormwater/ms4_sms/viewer.htm)

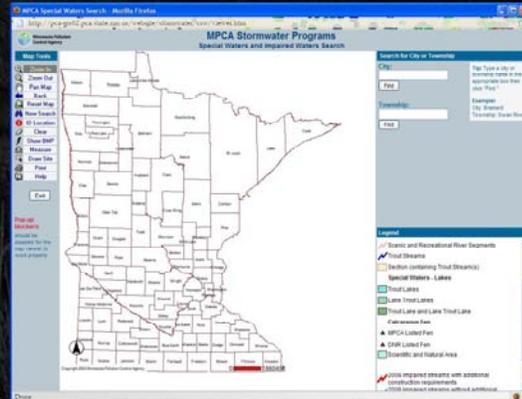


## Step 3 – Continued

Step 3.5 – Does the project drain to a special or impaired water?



Check the MPCA website to determine:  
<http://pca-gis04.pca.state.mn.us/webiste/stormwater/csw/viewer.htm>



LRRB Selecting Stormwater BMPs

# Step 4 – Create a Preliminary BMP Toolbox

Step 4 – Create a Preliminary BMP Toolbox

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Compare the BMPs included in the resource guide to narrow the list of potential BMPs that meet the regulatory environment. The list covers the majority of BMPs typically used in Minnesota but should not be considered an exhaustive list of all potential BMPs.

**3.3** Does your project fall within a watershed district or watershed management organization with permitting authority or that will need to review and approve the project? (Answer questions a-e in the table below to determine)

- Watershed district and watershed management organizations typically have the **MOST STRINGENT** requirements for stormwater management.
- For a listing of potential agencies and their contact information, go to [http://www.dnr.state.mn.us/permits/water/water\\_perm\\_contacts.html](http://www.dnr.state.mn.us/permits/water/water_perm_contacts.html)

Fill in the name(s) of the watershed agencies:

- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_

Contact each of the potential agencies listed and fill in their criteria for the following questions in the table below:

	Watershed Agency 1	Watershed Agency 2	Watershed Agency 3	Watershed Agency 4
a. Is rate control required (y/n)?				
b. Is volume control (y/n) required?				
c. Is water quality treatment (y/n) required? If yes, what is the specified % removal required for:				
Total phosphorus (TP):				
d. Do the BMPs need to provide for downstream channel protection (y/n)? See definition with 3.2.				
e. Does the project need to meet an anti-degradation (nondegradation) requirement to comply with a MMS permit (y/n)? See information with 3.2.				

**3.4** Based upon the answers to Questions 3.2 through 3.3, check the box to the right if you answered "yes" to any of the questions for any agency. For % removal of TSS and TP, list the **MOST STRINGENT** (highest) value of all agencies reviewed:

Check all that apply:

Rate control:

Volume control:

Water quality treatment:

  % TSS removal required:

  % TP removal required:

Channel protection:

Nondegradation:

**3.5** Does the project drain to a special or impaired water as defined by the MPCA? Yes / No  
 Check <http://pcr-a.gis2.pca.state.mn.us/webdata/stormwater/low/lowwater.htm>

Using this information, go to Step 4 to start creating a BMP toolbox specific to your project.

STORMWATER BMPs - DECISION TREE | Site - Low Available Space | Page 5 of 11

Goal = end up with two or three potential BMPs

Information for the various BMPs is presented in a table according to the type of project and the anticipated percentage of available space for surface BMPs.



# Step 4 – Continued

TABLE 4 – PRELIMINARY BMP TOOLBOX FOR SITE PROJECTS WITH LIMITED AVAILABLE SPACE\*

	BMP Category							
	Stormwater Fund (e.g., ponds with permanent pools of water, such as BMP ponds, and water reuse ponds)	Retention (e.g., wet ponds, bio-retention, bio filtration, and bio control)	Underground Treatment Devices (e.g., proprietary high-pressure separation, sand catch basins and wet wells)	Underground Detention (e.g., plan gardens, concrete vaults, proprietary storage systems generally used for stormwater retention of water and site control)	Infiltration (e.g., surface practices that do not rely on separation basins and underground systems connected pipe collection)	Permeable Pavements (e.g., porous asphalt, porous concrete, permeable pavers, vegetated/interlocked grids)	Tree or Planter Box (e.g., tree pits, tree box filters, permeable paving)	
<b>Primary Treatment Provided (See question 3.4)</b>								
a. Total Solids	REC	NA	NA	REC	MAYBE	REC	NA	
b. Volume Control	NA	REC	NA	NA	REC	REC	MAYBE	
c. Water Quality	REC	REC	MAYBE	NA	REC	MAYBE	MAYBE	
— TSS Removal Required (%)	60-90%	60-100%	30%	2-20%	100%	60-100%	65-100%	
— TP Removal Required (%)	34-72%	60-100%	0%	0%	60-100%	60-100%	60-100%	
d. Channel Protection	REC	MAYBE	NA	REC	MAYBE	MAYBE	MAYBE	
e. Nonvegetation requirement	MAYBE	REC	NA	REC	REC	MAYBE	MAYBE	
Comments	Retention practices depend on the type of pond. Wet extended detention basins are the only type of pond complying with the NPDES.	Higher removal efficiencies are achieved when retention basins are very sensitive to construction techniques and good site management.	Use existing pipe treatment device in many instances.	Typically only used for water control.	For treatment is required. Very sensitive to construction techniques.	Higher removal efficiencies are achieved when permeable pavements are very sensitive to construction techniques.	Avoid use of large trees from high-street areas. Retention efficiencies are not yet well documented. Higher removal efficiencies are achieved when retention practices are used.	Avoid use of large trees from high-street areas. Retention efficiencies are not yet well documented. Higher removal efficiencies are achieved when retention practices are used.
Soil Type Considerations (See Question 2.3)	Soil suited for HSG B, C or D soils. Use in HSG A, HSG A.4, and HSG D soils and permeable pavement.	Soil suited for HSG A and B soils. Use in HSG C or D soils and permeable pavement.	No restrictions based on foundation and ground.	No restrictions based on foundation and ground.	Soil suited for HSG A and B soils. NOT recommended for use in HSG C or D soils. Requires measures for building foundations and other items.	Soil suited for HSG A and B soils. Use in HSG C or HSG D soils.	Soil suited for HSG A and B soils. Use in HSG C or D soils and permeable pavement.	
Project Setting (See Question 2.4)	Central Business District, Downtown, Commercial, Office, Institutional, Residential, Retail, School, Transit Station	Central Business District, Downtown, Commercial, Office, Institutional, Residential, Retail, School, Transit Station	Central Business District, Downtown, Commercial, Office, Institutional, Residential, Retail, School, Transit Station	Central Business District, Downtown, Commercial, Office, Institutional, Residential, Retail, School, Transit Station	Central Business District, Downtown, Commercial, Office, Institutional, Residential, Retail, School, Transit Station	Central Business District, Downtown, Commercial, Office, Institutional, Residential, Retail, School, Transit Station	Central Business District, Downtown, Commercial, Office, Institutional, Residential, Retail, School, Transit Station	
Special Site Considerations (See Question 2.5)								
a. There are no special site considerations.	NA	REC	REC	NA	REC	REC	REC	
b. Subgrade/soil conditions	NA	REC	REC	NA	REC	REC	REC	
Check slope with BMCA.	NA	MAYBE	MAYBE	NA	REC	REC	REC	
L/S: Less than 3 feet to bedrock or seasonal high groundwater table.	NA	MAYBE	MAYBE	NA	REC	REC	REC	
c. PFI runoff	NA	REC	REC	NA	REC	REC	REC	
d. DUST, MUD, SAND, or sensitive groundwater	NA	MAYBE	MAYBE	NA	REC	REC	REC	
e. DRAINAGE TO SPECIAL or IMPAIRED WATER	NA	MAYBE	MAYBE	NA	REC	REC	REC	
Drainage to Special or Impaired Water (See Question 3.5)	NA	MAYBE	MAYBE	NA	REC	REC	REC	

\*STORMWATER BMPs - DECISION TREE | Site - Low Available Space



# Step 4 – Continued

	<b>Stormwater Pond</b> (e.g., ponds with permanent pools of water, such as NURP ponds, and multi-cell ponds)	<b>Bioretention</b> (e.g., rain gardens, bio-infiltration, bio-filtration, and bio-swales)
<b>Primary Treatment Provided</b> (See question 3.4)		
a. Rate Control	<b>REC</b>	<b>N/A</b>
b. Volume Control	<b>N/A</b>	<b>REC</b>
c. Water Quality	<b>REC</b>	<b>REC</b>
TSS Removal Required (%)	60-90%	85-100%
TP Removal Required (%)	34-73%	65-100%
d. Channel Protection	<b>REC</b>	<b>MAYBE</b>
e. Nondegradation requirement	<b>MAYBE</b>	<b>REC</b>
Comments	<ul style="list-style-type: none"> <li>- Removal efficiencies depend on the type of pond.</li> <li>- Wet extended detention basins are the only type of pond complying with the NPDES Permit.</li> </ul>	<ul style="list-style-type: none"> <li>- Higher removal efficiencies are when designed as bio-infiltration basins.</li> <li>- Very sensitive to construction techniques and good plant establishment.</li> </ul>
<b>Soil Type Considerations</b> (See Question 2.3)	Best suited for <b>HSG B, C or D</b> soils. Line ponds in HSG A & some HSG B soils to maintain a permanent pool.	Best suited for <b>HSG A and B</b> soils. Use in HSG C or D soils will require special soil mixes and underdrains.
<b>Project Setting</b> (See Question 2.4)	Central Business District Residential, Suburban, Campus, Low Density Commercial Rural/Undeveloped Land	Central Business District Residential, Suburban, Campus, Low Density Commercial Rural/Undeveloped Land





# Step 4 – Continued

Project Setting (See Question 2.4)	Central Business District	Residential, Suburban, Campus, Low Density Commercial	Rural/Unde- veloped Land	Central Business District	Residential, Suburban, Campus, Low Density Commercial	Rural/Unde- veloped Land
<b>Special Site Considerations (See Question 2.5)</b>						
a. There are no special site considerations.	N/A	REC	REC	N/A	REC	REC
b. Soil/groundwater contamination <i>Check design with MPCA.</i>	N/A	MAYBE	MAYBE	N/A	REC – May require liner depending on type of contamination.	
c/d. Less than 3 feet to bedrock or seasonal high groundwater table	N/A	MAYBE – Potential construction issues due to shallow bedrock.		N/A – NOT RECOMMENDED Look at rainwater reuse if volume reduction is required.		
e. PSH runoff	N/A	REC – May require liner and excellent pre-treatment.		N/A	MAYBE – Use impermeable liner and underdrain.	
f. DWSMA, WHPZ, karst, or sensitive groundwater	N/A	MAYBE – May require liner to prevent interaction with groundwater. <b>NOT recommended in karst areas.</b>		N/A	MAYBE – Depending on land use, may require impermeable liner and underdrain.	
<b>Drainage to Special or Impaired Water</b> (See Question 3.5)	N/A	MAYBE	MAYBE	N/A	REC – With cautions for use related to PSHs.	



# Step 5 – Refine BMP Selection/Select the Right “Tool”

**Step 5 – Refine BMP Selection/Select the Right “Tool”**

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This step allows the user to further refine the selection by comparing such factors as potential maintenance, potential life cycle costs, and aesthetics.

**STEP 5 – REFINE BMP SELECTION/SELECT THE RIGHT “TOOL.”**  
 This step allows you to further refine the selection by comparing such factors as maintenance, life cycle costs and aesthetics.

In **Step 4**, you came up with a list of two or three BMPs that could be appropriate for your project. Use the following **Table 5**, to compare other factors for each of those BMPs that will help narrow the list further. Highlight or circle the information as you go.

In the tables, BMPs are ranked as follows:  
**Capital Costs** – The average ranges are given relative to each other given identical areas being treated.  
**Maintenance Burden** – The average cost includes more frequent, minor inspection/maintenance work as well as less frequent, major maintenance work such as dredging or system replacement.  
**Relative Life Expectancy** – Life expectancies for the various BMPs are compared against each other, assuming that the design of each BMP was appropriate to their specific drainage areas.

Instructions

Step 1 – Select Stormwater

Step 2 – Select Stormwater

Step 3 – High Available Space

Step 4 – Low Available Space

Step 5 – High Available Space

Step 6 – Low Available Space

Appendices

LRRB Selecting Stormwater BMPs

STORMWATER BMPs • DECISION TREE | Site – Low Available Space

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# Step 5 – Continued

TABLE 5 – Final BMP Screening<sup>1,2</sup>

	BMP Category						
	Stormwater Pond <i>(e.g., ponds with permanent ponds of water, such as water ponds, and municipal ponds)</i>	Bioretention <i>(e.g., wet ponds, bio-retention, bio-retention, and tree wetlands)</i>	Underground Treatment Devices <i>(e.g., sand filtration, concrete vaults, hydrocarbon separators, sump catch basins, and wet vaults)</i>	Underground Detention <i>(e.g., sand filtration, concrete vaults, proprietary storage systems generally used for stormwater detention of water and rain control)</i>	Infiltration <i>(e.g., surface practices that do not rely on retention, such as tree or rock basins) and underground systems (perforated pipe galleries)</i>	Permeable Pavement/Permeable Paving <i>(e.g., porous asphalt, porous concrete, permeable pavers, reinforced concrete)</i>	Tree or Planter Box <i>(e.g., tree wells, tree box trees, stormwater planters)</i>
<b>Logistic Cost</b>	Low <sup>3</sup>	Medium <sup>3</sup>	High	Medium to high	High	Medium to high	Medium
<b>Maintenance Burden</b>	Easy to medium	Medium	Medium	Medium to difficult (depends on device)	Medium to difficult (depends on device)	Medium	Easy to medium
<b>Ease of Maintenance (See Note 3)</b>	Easy to medium	Medium	Medium	Medium to difficult (depends on device)	Medium to difficult (depends on device)	Medium	Easy to medium
<b>Typical Annual Operations and Maintenance Costs</b>	Low	Low	Medium to high	Low to medium	High	Medium to high	Low to medium
<b>Typical Major Maintenance Costs</b>	High	Medium to high	Medium to high	High	High	High	Medium <sup>4</sup>
<b>Frequency of Major Maintenance</b>	Low – Every 3 – 25 years	Medium to high – Every 1 – 5 years	Low	Low – Every 1 – 25 years	Medium – Every 2 – 5 years	Low to medium	Medium to high – Every 1 – 5 years <sup>5</sup>
<b>Relative Life Expectancy</b>	High	Medium	Medium	Medium to high	Medium	Low to medium	Low to medium
<b>Relative Life Cycle Cost</b>	Low to medium	Medium	High	Medium to high	High	Medium to high	Medium
<b>Cost Effectiveness</b>							
<b>DOCs (\$/lb)<sup>6</sup></b>							
<b>TSS Removal</b>	\$218	\$150	Not available	Typically not used for water quality filtering	Not available	\$20 - \$150	\$165
<b>TP Removal</b>	\$85,100	\$52,300	Not available	Typically not used for water quality filtering	Not available	\$5,900 - \$75,300	\$4,200
<b>Cost Effectiveness per Acre Treated (DOCs \$/acre)</b>	\$35,300	\$28,900	Not available	\$52,300	Not available	\$5,300 - \$25,200	\$26,800
<b>Other Factors</b>	Can be designed as an integral part of a site's stormwater management system. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.	Typically designed as part of the surrounding site, but requires regular maintenance (e.g., mowing, weeding, etc.) to maintain appearance.	Typically not visible	Typically not visible	Depending on the design, above-ground systems require less maintenance. Underground systems have no maintenance required.	Depending on system used, they can be used as an aesthetic feature. Permeable pavement and porous concrete applications may have low maintenance requirements.	Typically designed as part of the surrounding site, but requires regular maintenance (e.g., mowing, weeding, etc.) to maintain appearance.
<b>Resilience Factors</b>	Medium to high potential for installation in urban areas. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.	Medium potential for installation in urban areas. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.	Medium potential for installation in urban areas. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.	Typically do not require extensive maintenance. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.	Permeable pavement and porous concrete applications may have low maintenance requirements. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.	Medium potential for installation in urban areas. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.	Medium potential for installation in urban areas. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.
<b>Safety Concerns</b>	Medium potential for installation in urban areas. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.	Medium potential for installation in urban areas. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.	Medium potential for installation in urban areas. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.	Medium potential for installation in urban areas. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.	Medium potential for installation in urban areas. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.	Medium potential for installation in urban areas. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.	Medium potential for installation in urban areas. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.
<b>Soil Containment</b>	Medium potential for installation in urban areas. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.	Medium potential for installation in urban areas. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.	Medium potential for installation in urban areas. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.	Medium potential for installation in urban areas. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.	Medium potential for installation in urban areas. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.	Medium potential for installation in urban areas. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.	Medium potential for installation in urban areas. Stormwater ponds can be designed to provide aesthetic benefits to the surrounding area.

See table notes on the following page.

Interactions  
Low-Aesthetics Storm  
High-Aesthetics Storm  
Low-Aesthetics Storm  
High-Aesthetics Storm  
Aesthetics



## Step 5 – Continued

	<b>Stormwater Pond</b> (e.g., ponds with permanent pools of water, such as NURP ponds, and multi-cell ponds)	<b>Bioretention</b> (e.g., rain gardens, bio-infiltration, bio-filtration, and bio-swales)
<b>Capital Cost</b>	Low <sup>a</sup>	Moderate <sup>a</sup>
<b>Maintenance Burden</b>		
Ease of Maintenance (Mn Stm Man)	Easy to medium	Medium
Typical Annual Operations and Maintenance Costs	Low	Low
Typical Major Maintenance Costs	High	Medium to high
Frequency of Major Maintenance	Low – Every 5 - 25 years	Medium to high – Every 1 - 5 years
<b>Relative Life Expectancy</b>	High	Medium
<b>Relative Life Cycle Cost</b>	Low to moderate	Moderate



LRRB Selecting Stormwater BMPs



## Step 5 – Continued

Cost Effectiveness per Acre Treated (2005 \$/acre)	\$30,500	\$25,900
<b>Other Factors</b>		
Aesthetics	Can be designed as an amenity but success is dependent upon appropriate sizing of the pond for the drainage area. In highly visible areas, pre-treatment may be desired to remove trash prior to discharging to the pond.	Typically designed as part of the landscaping plan, but requires regular weeding/plant maintenance to maintain appearance.
Nuisance Factors	Moderate to high potential for mosquitoes or other nuisance insects, geese, floatables and odors.	Moderate potential for mosquitoes or other nuisance insects and overgrown vegetation.
Safety Concerns	A safety bench is strongly recommended, but may still pose safety concern for drowning. Berms that function as dams have a potential to fail.	Typically do not pose any safety concerns.
Spill Containment	Can provide a high degree of protection if outlet designed to provide skimming.	Minimal protection for bio-infiltration without upstream spill containment manhole. Moderate to high protection for bio-infiltration if outlet for underdrains can be blocked.



LRRB Selecting Stormwater BMPs





## Step 5 – Continued

### Notes for Table 5:

<sup>a</sup> Does not include the cost to acquire land if the BMP is not located in a remnant parcel or outlot.

<sup>b</sup> Major maintenance work is dependent on the system and its intended use. For instance, if the tree box filter treats only its immediate surroundings, once the tree canopy develops, rainfall is intercepted prior to reaching the ground. In this case, the owner may decide to reduce major maintenance tasks. However, if the BMP is designed for infiltration and evapotranspiration of runoff from a larger area, major maintenance tasks must be performed in order for the BMP to continue providing treatment for this area.

<sup>a</sup> For consistency, the cost effectiveness for each BMP category was determined using the present value of whole life costs using the WERF whole life costs spreadsheet tools (published 2005) as determined for a 10-acre residential watershed with ¼-acre lots (38% impervious) in HSG B soils. The annual TSS and TP loadings were determined using P8, and the removal efficiency of each BMP was assumed to be the average the range given in Tables 3.A through 3.D. Each BMP was assumed to have a "Medium" level of maintenance for consistency; the WERF spreadsheet tool has costs associated with Low, Medium and High levels of maintenance, which vary for each BMP category. The square footage of the porous/pervious/permeable pavements was assumed to be 10% of the impervious surface, and the capital costs were assumed to be "High" in order to compensate for deeper aggregate sections that may be typically used in cold weather climates.

Annual TSS Loading = 1894.3 pounds  
Annual TP Loading = 6.0 pounds

<sup>1</sup> Minnesota Pollution Control Agency, Minnesota Stormwater Manual, Version 2, 2005. The Minnesota Stormwater Manual provided the majority of the information in the table unless noted.

<sup>2</sup> New Hampshire Stormwater Manual, Vol. 2, Revision: 1.0, Appendix B BMP Pollutant Removal Efficiency, 2008.

<sup>3</sup> Virginia Stormwater Management Program, Technical Bulletin #6: Minimum Standard 3.11C Filterra Bioretention Filter System, revised November, 1, 2002.





## Summary of 5-Step Process

- Assists during the scoping phase of your projects.
  - Typically used when a regional pond is not available.
- Helps select BMPs based upon their performance and your project requirements.
- Provides documentation for how decisions have been made.





## Resources

- The Cost and Effectiveness of Stormwater Management Practices. <http://www.lrrb.org/pdf/200523.pdf>
- Stormwater Treatment: Assessment and Maintenance. <http://stormwaterbook.safl.umn.edu/>
- Hydrodynamic Separator Sediment Retention Testing. <http://www.cts.umn.edu/Publications/ResearchReports/reportdetail.html?id=1890>
- International Stormwater Database, 2007. <http://www.bmpdatabase.org/>





## Resources

- Minnesota Stormwater Manual, version 2.  
<http://www.pca.state.mn.us/index.php/water/water-types-and-programs/stormwater/stormwater-management/minnesota-s-stormwater-manual.html>
- Urban Stormwater Management in the United States from the National Academy of Sciences.  
[http://www.nap.edu/catalog.php?record\\_id=12465#toc](http://www.nap.edu/catalog.php?record_id=12465#toc)
- Post-Project Monitoring of BMPs/SUDS to Determine Performance and Whole-Life Costs, Vol. 1.  
<http://www.werf.org/AM/Template.cfm?Section=Search&Template=/CustomSource/Research/PublicationProfile.cfm&id=01-CTS-21T>



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## Resources

- Performance and Whole Life Costs of Best Management Practices (BMPs) and Sustainable Urban Drainage Systems (SUDS), Vol.2.
  - Main Document:  
<http://www.werf.org/AM/Template.cfm?Section=Search&Template=/CustomSource/Research/PublicationProfile.cfm&id=01-CTS-21-TA>
  - Whole Life Cost Tool:  
<http://www.werf.org/AM/Template.cfm?Section=ResearchProfile&Template=/CustomSource/Research/PublicationProfile.cfm&id=SW2R08>





## Resources

- A Public Works Perspective on the Cost vs. Benefit of Various Stormwater Management Practices.  
[http://www.co.washington.mn.us/client\\_files/documents/phe/ENV/GW-CostBenefit.pdf](http://www.co.washington.mn.us/client_files/documents/phe/ENV/GW-CostBenefit.pdf)
- The Economics Of Structural Stormwater BMPs In North Carolina.  
<http://www.bae.ncsu.edu/stormwater/PublicationFiles/EconStructuralBMPs2003.pdf>
- Iowa Stormwater Management Manual, ver. 2.  
<http://www.intrans.iastate.edu/pubs/stormwater/index.cfm>





## Questions?

LRRB website: [www.lrrb.org](http://www.lrrb.org)

Find the Decision Tree and this presentation at  
<http://www.lrrb.org/pdf/2011RIC01.pdf>



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