Appendix M

Decision Trees for Selecting Best Management Practices

Minnesota Department of Health (labeled Appendix A, as provided)

Idaho Department of Environmental Quality (labeled Figure 2, as provided)

Stormwater Center

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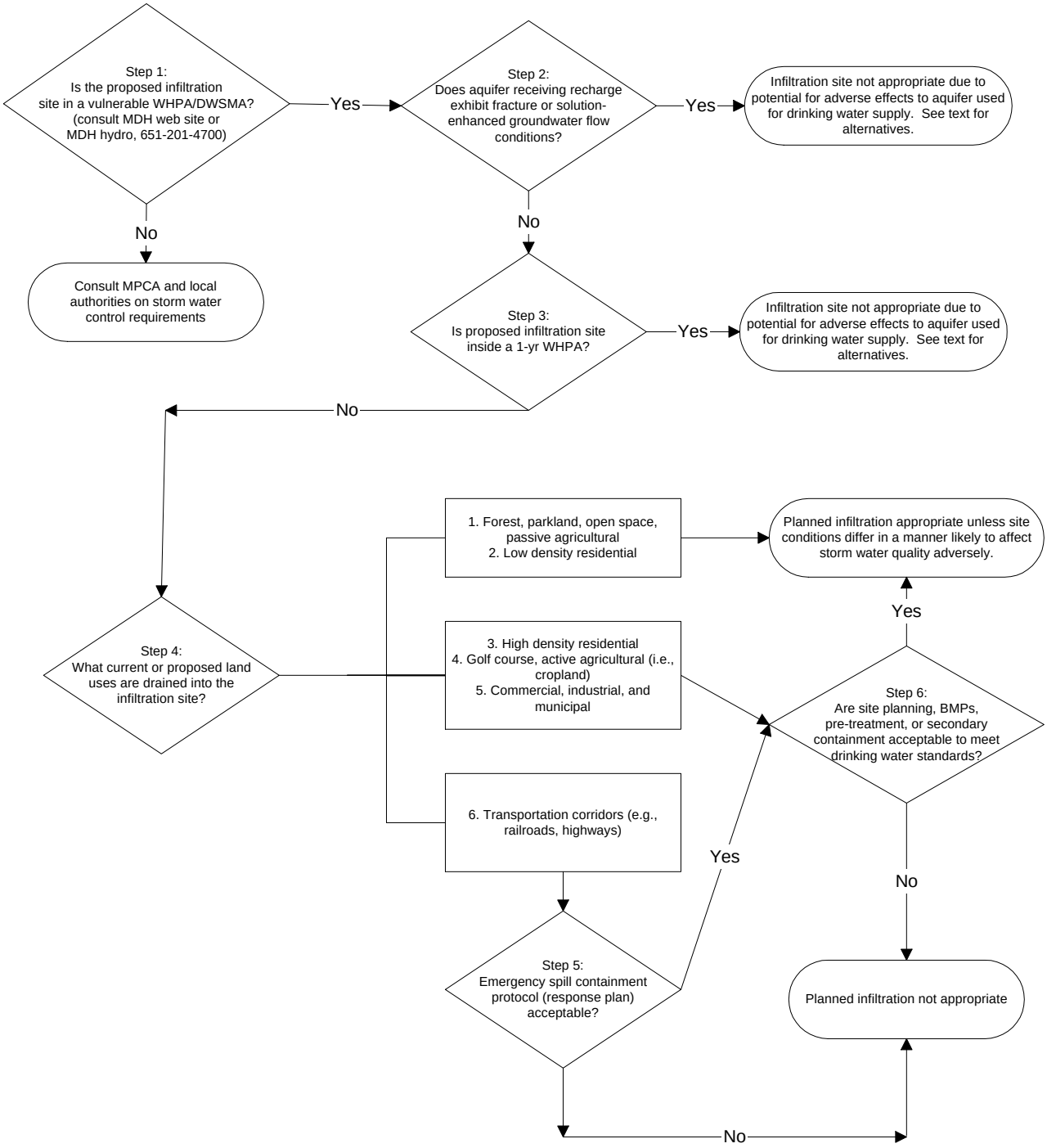
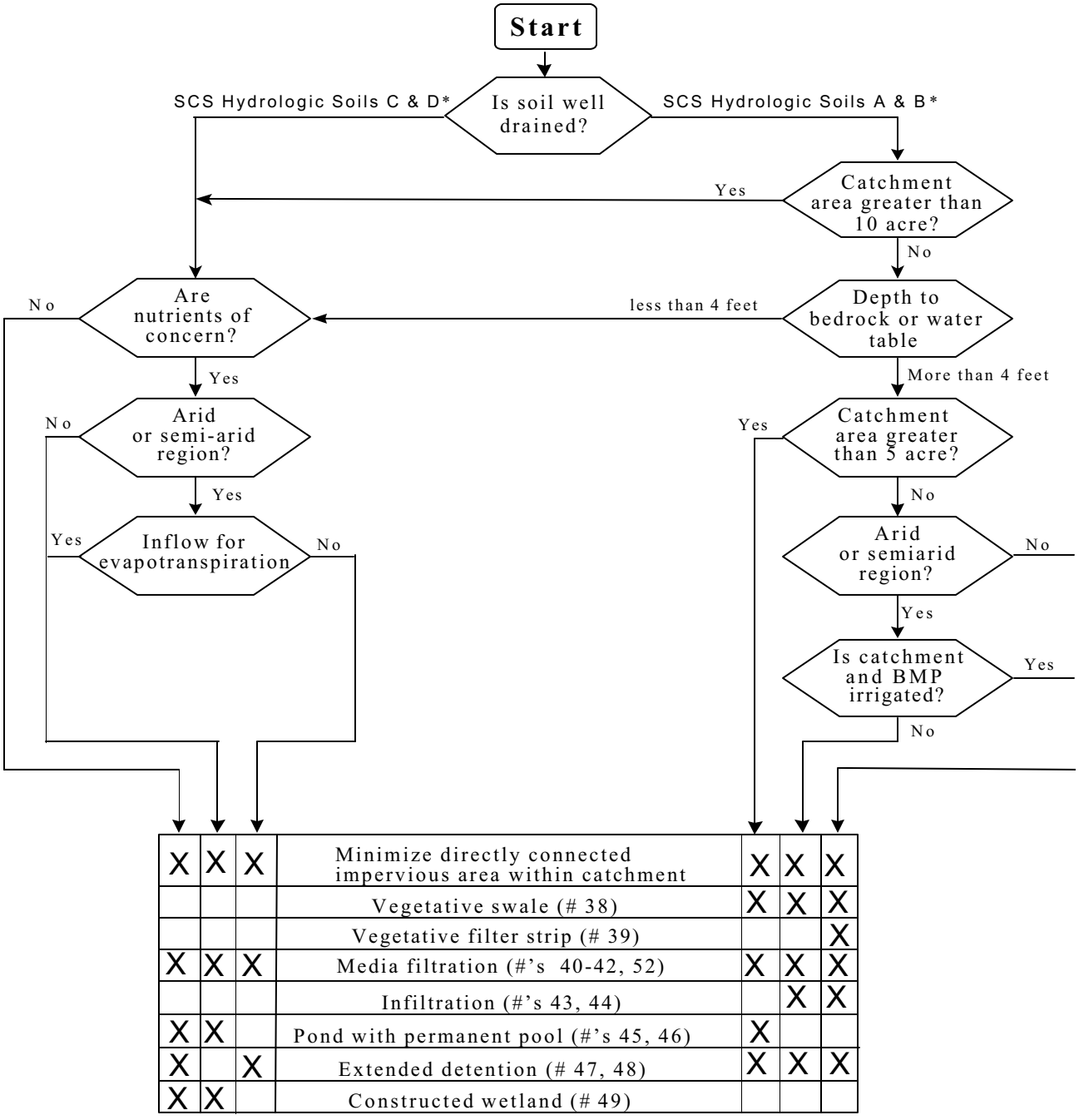
Appendix A.
A Flow Chart for Evaluating Proposed Storm Water Infiltration Projects in Areas with Vulnerable Groundwater



Note: This flow chart intended for use in conjunction with MDH guidance on evaluating storm water infiltration projects in wellhead protection areas.



X	X	X	Minimize directly connected impervious area within catchment	X	X	X
			Vegetative swale (# 38)	X	X	X
			Vegetative filter strip (# 39)			X
X	X	X	Media filtration (#'s 40-42, 52)	X	X	X
			Infiltration (#'s 43, 44)		X	X
X	X		Pond with permanent pool (#'s 45, 46)	X		
X		X	Extended detention (# 47, 48)	X	X	X
X	X		Constructed wetland (# 49)			

Figure 2. The design professional=s decision tree for selecting appropriate storm water practices and methods. The numbers in the above box refer to permanent storm water practices and methods contained in Chapter 5 of the Catalog, as listed by numbered fact sheet. Also, Catalog=s Table 3-1 contains targeted pollutants and site suitability criteria (page 9 herein). Based on page 181 of AUrban Runoff Quality Management@ (1998, Water Environment Federation and American Society of Civil Engineers). *SCS (or Soil Conservation Service) = Natural Resource Conservation Service.

STP Screening Matrices

This section presents a series of matrices that can be used as a screening process for selecting the best STP or group of STPs for a development site. It also provides guidance for locating practices on the site. The matrices presented can be used to screen practices in a step-wise fashion. Screening factors include:

- Land Use
- Physical Feasibility
- Climate/Regional Factors
- Watershed Factors
- Stormwater Management Capability
- Pollutant Removal
- Community and Environmental Factors

The matrices presented here are not exhaustive. Specific additional criteria may be incorporated depending on local design knowledge and resource protection goals. Furthermore, many communities may wish to eliminate some of the selection factors presented in this section. Caveats for the application of each matrix are included in the detailed description of each.

In the matrices presented below, several specific numerical requirements are included, and may vary between communities.

Most of the material in the screening matrices provides technical guidance, and is not necessarily a regulatory mandate. In the few cases where a screening element would typically be a regulatory requirement, cells are shaded.

More detail on the proposed step-wise screening process is provided below:

Step 1. Land Use

Which practices are best suited for the proposed land use at this site? In this step, the designer makes an initial screen to select practices that are best suited to a particular land use.

Step 2. Physical Feasibility Factors

Are there any physical constraints at the project site that may restrict or preclude the use of a particular STP? In this step, the designer screens the STP list using Matrix No. 2 to determine if the soils, water table, drainage area, slope or head conditions present at a particular development site might limit the use of a STP. In addition, the matrix indicates which STP options work well in highly urban areas.

Step 3. Climate/Regional Factors

Are there any regional characteristics that restrict or modify the use of certain STPs? Matrix No. 3 details potential modifications to STP selection based on climate and geology.

Step 4. Watershed Factors

What watershed protection goals need to be met in the resource my site drains to? Matrix No.4 outlines STP goals and restrictions based on the resource being protected.

Step 5. Stormwater Management Capability

Can one STP meet all design criteria, or is a combination of practices needed? In this step, designers can

screen the STP list using Matrix No. 5 to determine if a particular STP can meet recharge, water quality, channel protection, and flood control storage requirements. At the end of this step, the designer can screen the STP options down to a manageable number and determine if a single STP or a group of STPs are needed to meet stormwater sizing criteria at the site.

Step 6. Pollutant Removal

How do each of the STP options compare in terms of pollutant removal? In this step, the designer views removal of select pollutants to determine the best STP options for water quality.

Step 7. Community and Environmental Factors

Do the remaining STPs have any important community or environmental benefits or drawbacks that might influence the selection process? In this step, a matrix is used to compare the twenty STP options with regard to maintenance, habitat, community acceptance, cost and other environmental factors.

Step 1. Land Use

This matrix allows the designer to make an initial screen of practices most appropriate for a given land use.

Rural. This column identifies STPs that are best suited to treat runoff in rural or very low density areas.

Residential. This column identifies the best treatment options in medium to high density residential developments.

Roads and Highways. This column identifies the best practices to treat runoff from major roadways and highway systems.

Commercial Development. This column identifies practices that are suitable for new commercial development

Hotspot Land Uses. This last column examines the capability of an STP to treat runoff from designated hotspots. An STP that receives hotspot runoff may have design restrictions, as noted.

Ultra-Urban Sites. This column identifies STPs that work well in the ultra-urban environment, where space is limited and original soils have been disturbed. These STPs are frequently used at redevelopment sites.

STP Selection Matrix 1. Land Use

STP Group	STP Design	Rural	Residential	Roads and Highways	Commercial/ High Density	Hotspots	Ultra Urban
Pond	Micropool ED	○	○	○	◗	①	●
	Wet Pond	○	○	○	◗	①	●
	Wet ED Pond	○	○	○	◗	①	●
	Multiple Pond	○	○	◗	◗	①	●
	Pocket Pond	○	◗	○	◗	●	●
Wetland	Shallow Marsh	○	○	◗	◗	①	●
	ED Wetland	○	○	◗	◗	①	●
	Pond/Wetland	○	○	●	◗	①	●
	Pocket Marsh	○	◗	○	◗	●	●
Infiltration	Infiltration Trench	◗	◗	○	○	●	◗
	Shallow I-Basin	◗	◗	◗	◗	●	◗
Filters	Surface Sand	●	◗	○	○	②	○
	Underground SF	●	●	◗	○	○	○
	Perimeter SF	●	●	◗	○	○	○
	Organic SF	●	◗	○	○	②	○
	Pocket Sand Filter	●	◗	○	○	②	○
	Bioretention	◗	◗	○	○	②	○
Open Channels	Dry Swale	○	◗	○	◗	②	◗
	Wet Swale	○	●	○	●	●	●
	Grass Channel	○	◗	○	◗	●	◗

○: **Yes. Good option in most cases.**

◗: **Depends. Suitable under certain conditions, or may be used to treat a portion of the site.**

●: **No. Seldom or never suitable.**

①: **Acceptable option, but may require a pond liner to reduce risk of groundwater contaminination.**

②: **Acceptable option, if not designed as an exfilter.**

Note that, while most of the land use decisions serve primarily as guidance, hotspot restrictions should typically be regulatory.

Step 2. Physical Feasibility Factors

This matrix allows the designer to evaluate possible options based on physical conditions at the site. More detailed testing protocols are often needed to confirm physical conditions at the site. Five primary factors are:

Soils. The key evaluation factors are based on an initial investigation of the NRCS hydrologic soils groups at the site. Note that more detailed geotechnical tests are usually required for infiltration feasibility and during design to confirm permeability and other factors.

Water Table. This column indicates the minimum depth to the seasonally high water table from the bottom elevation, or floor, of an STP.

Drainage Area. This column indicates the minimum or maximum drainage area that is considered optimal for a practice. If the drainage area present at a site is slightly greater than the maximum allowable drainage area for a practice, some leeway is warranted where a practice meets other management objectives. Likewise, the minimum drainage areas indicated for ponds and wetlands should not be considered inflexible limits, and may be increased or decreased depending on water availability (baseflow or groundwater), mechanisms employed to prevent clogging, or the ability to assume an increased maintenance burden.

Slope. This column evaluates the effect of slope on the practice. Specifically, the slope guidance refers to how flat the area where the practice is installed must be and/or how steep the contributing drainage area or flow length can be.

Head. This column provides an estimate of the elevation difference needed for a practice (from the inflow to the outflow) to allow for gravity operation.

The Physical Feasibility Matrix provides specific feasibility criteria. The criteria in this matrix are adapted from the Maryland Stormwater Design Manual. Each community needs to select specific criteria that are appropriate for their region, and consistent with local design experience.

STP Selection Matrix 2. Physical Feasibility

STP Group	STP Design	SOILS	WATER TABLE	DRAINAGE AREA (acres)	SITE SLOPE	HEAD (ft)
Pond	Micropool ED	HSG A soils may require pond liner.	2 foot separation if hotspot or aquifer	10 min*	No more than 15%	6 to 8 ft
	Wet Pond			25 min*		
	Wet ED Pond					
	Multiple Pond					
	Pocket Pond	OK	below WT	5 max**		4 ft
Wetland	Shallow Marsh	HSG A soils may require liner	2 foot separation if hotspot or aquifer	25 min	No more than 8%	3 to 5 ft
	ED Wetland					
	Pond/Wetland					
						2 to 3

	Pocket Marsh	OK	below WT	5 max		ft
Infiltration	Infiltration Trench	f_c > 0.5 inch/hr	4 feet	5 max	No more than 6%	1 ft
	Shallow I-Basin			10 max		3 ft
Filters	Surface Sand Filter	OK	2 feet	10 max **	no more than 6%	5 ft
	Underground SF			2 max **		5 to 7ft
	Perimeter SF			2 max **		2 to 3 ft
	Organic SF			5 max**		2 to 4 ft
	Pocket Sand Filter			5 max **		2 to 5 ft
	Bioretention	Made Soil				5 ft
Open Channels	Dry Swale	Made Soil	2 feet	5 max	No more than 4%	3 to 5 ft
	Wet Swale	OK	below WT	5 max		1 ft
	Grass Channel	OK	2 feet	5 max		1 ft

Notes: OK= not restricted, WT= water table, PT = pretreatment, f_c =soil permeability

** unless adequate water balance and anti-clogging device installed ** drainage area can be larger in some instances.*

Step 3. Climate/Regional Factors

Both the design characteristics and the best practice for a site can be influenced by regional factors such as the topography, geography, or climate of a region. The following matrix identifies five regional factors, including:

Arid/ Semi-Arid. In these dry climates, the water conservation concerns may eliminate some practices from consideration. Furthermore, practices need to be designed to reflect the challenges in these regions.

Low Relief. In areas of low relief, particularly those that are in coastal regions, STPs that require minimal head and distance to groundwater are preferred.

Cold Climates. In cold climates, practice selection or design needs to incorporate features to deal with challenges such as winter snowmelt and frost heave.

Karst Topography. Areas of karst topography presents specific challenges to STP designers, including potential groundwater contamination and sinkhole formation.

High Rainfall. Regions that receive high annual rainfall, and particularly those areas that experience frequent hurricanes, make application of some practices challenging.

This matrix will likely not appear in its entirety in many Stormwater Design Manuals. If a manual is designed for a state, they may have some distinct climate zones, or areas of karst topography. Furthermore, a STP manual writer may choose to make finer distinctions, based on specific climate zones within a state.

Matrix 3. Climate/ Regional Factors

Stp Group	Arid/ Semi-arid	Low Relief (E.g., Coastal)	Cold Climates	Karst Topography	High Rainfall
Ponds	Conduct a water balance analysis. Supplemental water may be necessary.	Pond drain may not be feasible.	Incorporate design features to improve winter performance.	Encourage use of a clay liner to prevent sinkhole formation, infiltration of hotspot runoff. Conduct geotechnical tests to ensure that sinkholes do not form.	OK
Wetlands	Restricted use due to water supply.	OK	Encourage the use of salt-tolerant vegetation.	Allow a maximum ponding depth of no greater than 4 feet to	

				reduce the risk of sinkhole formation.	
Infiltration	OK	Check distance to GW table	Incorporate features to minimize the risk of frost heave. Discourage infiltration of chlorides.	For Karst where sinkholes may form, discourage use. For other Karst, encourage heavy pretreatment.	May require more frequent maintenance due to increased organic build-up in moist soils.
Filters	OK	Perimeter Sand Filter is best option	Incorporate design features to improve	OK	OK
Open Channels	Select drought-tolerant vegetation.	Ensure minimum slope can be achieved.	Encourage the use of salt-tolerant vegetation.	Carefully analyze infiltration when sink holes are a	Ensure a thick vegetative cover to reduce the risk of channel

While most climatic issues can be resolved with guidance, regulatory requirements should be in place to prevent groundwater contamination and sinkhole formation in karst regions.

Step 4. Watershed Factors

The design of urban STPs is fundamentally influenced by the nature of the downstream water body that will be receiving the stormwater discharge. Consequently, the designer needs to be cognizant of the goals in the resource the site drains to. This section includes selection criteria and design guidelines for the eight resource categories included in the Watershed Templates. These include:

- Sensitive Streams
- Impacted Streams
- Non-Supporting Streams
- Restorable Streams
- Aquifers
- Urban Lakes
- Reservoirs
- Estuaries/Shellfish Beds

Many jurisdictions may have specific requirements related to a specific resource, such as a particular reservoir. Others may have identified specific protection areas that include special requirements. The watershed factors presented here are generic, and based on the watershed templates.

STP Selection Matrix 4-1. Watershed Factors - Streams				
STP GROUP	**SENSITIVE STREAM**	**IMPACTED STREAM**	**NON-SUPPORTING STREAM**	**RESTORABLE STREAM**
Ponds	Require channel protection. Restrict in-stream practices. In cold water streams, minimize permanent pool area, and encourage shading.	Require channel protection.	Emphasize flood control when local flooding is a concern. Provide long detention times for bacteria control.	Require channel protection. Where possible, integrate design with watershed retrofit priorities.
Wetlands	Require channel protection. Restrict in-stream practices.	Require channel protection.	Emphasize flood control when local flooding is a concern. Provide long detention times for bacteria control.	Require channel protection. Where possible, integrate design with watershed retrofit

	Restrict use in cold-water streams.			priorities. Design in-stream wetland practices to support habitat restoration goals.
Infiltration	Strongly encourage use for groudwater recharge. Combine with a detention facility to provide channel protection.	Combine with a detention facility to provide channel protection.	Combine with a detention facility to provide flood control where appropriate. Avoid direct infiltration of hotspot runoff.	Combine with a detention facility to provide channel protection.
Filtering Systems	Combine with a detention facility to provide channel protection.	Combine with a detention facility to provide channel protection.	Combine with a detention facility to provide flood control where appropriate. Use as pretreatment prior to an infilration practice for hotspot runoff.	Combine with a detention facility to provide channel protection.
Open Channels	Combine with a detention facility to provide channel protection.	Combine with a detention facility to provide channel protection.	Combine with a detention facility to provide flood control where appropriate. Often restricted due to space limitations.	Combine with a detention facility to provide channel protection. Often restricted due to space limitations.
Note: For all stream systems, removal of specific pollutants may also be a goal, particularly when a stream does not meet water quality standards, is part of a TMDL watershed, or drains to a waterbody that has specific pollutant reduction targets.				

STP Selection Matrix 4-2. Watershed Factors - Other Aquatic Resources				
STP GROUP	**AQUIFER**	**URBAN LAKE**	**RESERVOIR**	**ESTUARY/ SHELLFISH BEDS**
Ponds	May require liner if HSG A soils are present.	Encourage the use of a large permanent pool to improve phosphorous removal.	Encourage the use of a large permanent pool to improve phosphorous removal.	Encourage long detention times to promote bacteria removal.

Wetlands	Pretreat hotspots. Provide a separation distance to water table.		Promote long detention times to encourage bacteria removal. Require channel protection.*	Provides high nitrogen removal.
Infiltration	Provide 100' horizontal separation distance from wells and 4' vertical distance from the water table. No hotspot runoff, unless pretreated by another practice, such as a filtering system. Require pretreatment of all runoff except rooftop.	OK. Provides high phosphorous removal.	Provide a separation distance from bedrock and water table Pretreat runoff prior to infiltration practices.	OK, but provide a separation distance to seasonally high groundwater.
Filtering Systems	Excellent pretreatment for infiltration or open channel practices.	OK, but designs with a submerged filter may result in phosphorous release.	Excellent pretreatment for infiltration or open channel practices. Moderate to high coliform removal	Moderate to high coliform removal Designs with a submerged filter bed appear to have very high nitrogen removal
Open Channels	OK, but hotspot runoff must be adequately pretreated	OK. Moderate P removal.	Poor coliform removal for wet swales.	Poor coliform removal for grass wet swales.

* Although channel protection is critical to prevent erosion of upstream channels draining to urban lakes and reservoirs, both flood control and channel protection requirements may be waived for sites that drain directly to reservoirs or lakes, or larger order streams.

Step 5. Stormwater Management Capability

This matrix examines the capability of each STP option to meet stormwater management criteria. It shows whether an STP can meet requirements for:

Water Quality. The matrix tells whether each practice can be used to provide water quality treatment effectively. For more detail, consult the pollutant removal matrix.

Recharge. The matrix indicates whether each practice can provide groundwater recharge, in support of recharge requirements. It may also be possible to meet this requirement using stormwater credits.

Channel Protection. The matrix indicates whether the STP can typically provide channel protection storage. The finding that a particular S TP cannot meet the channel protection requirement does not necessarily imply that the STP should be eliminated from consideration, but is a reminder that more than one practice may be needed at a site (e.g., a bioretention area and a downstream ED pond).

Quantity Control The matrix shows whether an STP can typically meet the overbank flooding criteria for the site. Again, the finding that a particular STP cannot meet the requirement does not necessarily mean that it should be eliminated from consideration, but rather is a reminder that more than one practice may be needed at a site (e.g., a bioretention area and a downstream stormwater detention pond)

This matrix will change depending on the criteria in place within a community. For example, many areas do not require recharge, and this criterion would not appear in their manuals. Second, this section places some practices that do not necessarily meet water quality goals on the "acceptable" list, and uses this matrix to screen them. Alternatively, a community may choose to restrict these practices from the original practice list.

STP Selection Matrix 5. Stormwater Management Capability

STP Group	STP Design	Water Quality?	Recharge?	Channel Protection?	Flood Control?
Pond	Micropool ED	○	●	○	○
	Wet Pond	○	●	○	○
	Wet ED Pond	○	●	○	○
	Multiple Pond	○	●	○	○
	Pocket Pond	○	●	○	○
Wetland	Shallow Marsh	○	●	○	○
	ED Wetland	○	●	○	○
	Pond/Wetland	○	●	○	○
	Pocket Marsh	○	●	○	❷
Infiltration	Infiltration Trench	○	○	❷	❸
	Shallow I-Basin	○	○	❷	❸
Filters	Surface Sand	○	❶	❷	●
	Underground SF	○	●	●	●
	Perimeter SF	○	●	●	●
	Organic SF	○	❶	●	●
	Pocket Sand Filter	○	❶	●	●
	Bioretention	○	❶	❷	●
Open Channels	Dry Swale	○	❶	●	●
	Wet Swale	○	●	●	●
	Grass Channel	❷	❷	●	●

○ **Practice generally meets this stormwater management goal.**

● **Practice can almost never be used to meet this goal.**

❶ **Provides recharge only if designed as an exfilter system.**

❷ **Practice may partially meet this goal, or under specific site and design conditions.**

❸ **Can be used to meet flood control in rare conditions, with very cobbly or highly infiltrative soils.**

It is important to note that very few practices can be used to achieve recharge. While some of the above practices have groundwater interaction, such as ponds, they cannot reliably provide recharge, as they tend to seal over time. Communities that have a recharge requirement should consider the use of stormwater credits to meet recharge requirements.

Each jurisdiction needs to explicitly dictate which practices can meet existing management goals. Thus, this entire matrix acts as a regulation rather than guidance.

Step 6. Pollutant Removal

This matrix examines the capability of each STP option to remove specific pollutants from stormwater runoff. The matrix includes data for:

- Total Suspended Solids
- Total Phosphorous
- Total Nitrogen
- Metals
- Bacteria

For more information on these and other pollutants, please consult the Pollutant Removal Database (in .pdf format)

In some communities, on-site load calculation is required, and this matrix is critical. In others, these values may be replaced with relative (i.e., "high, low, moderate") pollutant removals. Also, a community may choose to focus on only one or two target pollutants to protect a specific resource.

STP Selection Matrix 6. Pollutant Removal

STP Group	TSS	TP	TN	Metals[1]	Bacteria
Ponds	80	51	33	62	70
Wetlands	76	49	30	42	78[2]
Filters[3]	86	59	38	69	37[2]
Infiltration	95[2]	70	51	99[2]	N/A
Open Channels [4]	81	34[2]	84[2,5]	61	-25[2]

1: Average of zinc and copper. Zinc only for infiltration practices.
2: Based on fewer than five data points.
3: Excludes vertical sand filters and filter strips.
4: Highest removal rates for dry swales
5: No data available for grass channels
N/A: Data not available

Step 7. Community and Environmental Factors

The last step assesses community and environmental factors involved in STP selection. This matrix employs a comparative index approach. An open circle indicates that the STP has a high benefit and a dark circle indicates that the particular STP has a low benefit.

Maintenance. This column assesses the relative maintenance effort needed for an STP, in terms of three criteria: frequency of scheduled maintenance, chronic maintenance problems (such as clogging) and reported failure rates. It should be noted that **all STPs** require routine inspection and maintenance.

Community Acceptance. This column assesses community acceptance, as measured by three factors: market and preference surveys, reported nuisance problems, and visual orientation (i.e., is it prominently located or is it in a discrete underground location). It should be noted that a low rank can often be improved by a better landscaping plan.

Affordability. The STPs are ranked according to their relative construction cost per impervious acre treated. These costs exclude design, land aquisition, and other costs.

Safety. A comparative index that expresses the relative safety of an STP. An open circle indicates a safe STP, while a darkened circle indicates deep pools may create potential safety risks. The safety factor is included at this stage of the screening process because liability and safety are of paramount concern in many residential settings.

Habitat. STPs are evaluated on their ability to provide wildlife or wetland habitat, assuming that an effort is made to landscape them appropriately. Objective criteria include size, water features, wetland features and vegetative cover of the STP and its buffer.

The choice for values within this matrix is subjective. Communities may use different values, based on local experience.

STP Selection Matrix 7. Community and Environmental Factors

STP GROUP	STP LIST	EASE OF MAINTENANCE	COMMUNITY ACCEPTANCE	AFFORDABILITY	SAFETY	HABITAT
Ponds	Micropool ED	◗	◗	○	○	◗
	Wet Pond	○	○	○	●	○
	Wet ED Pond	○	○	○	●	○
	Multiple Pond	○	○	◗	●	○
	Pocket Pond	●	◗	○	◗	●
Wetlands	Shallow Marsh	◗	○	◗	○	○
	ED Wetland	◗	◗	◗	◗	○
	Pond/Wetland	○	○	◗	●	○
	Pocket Marsh	●	●	○	○	◗
Infiltration	Infiltration	●	○	◗	○	●
	Shallow I-Basin	●	●	◗	○	●
Filters	Surface SF	◗	◗	●	○	●
	Underground	●	○	●	◗	●
	Perimeter SF	●	○	●	○	●
	Organic SF	◗	○	●	○	●
	Pocket Sand	◗	◗	◗	○	●
	Bioretention	◗	◗	◗	○	◗
Open Channels	Dry Swale	○	○	◗	○	●
	Wet Swale	○	◗	○	○	◗
	Grass Channel	○	○	○	○	●

○ High ● Low ◗ Medium