

Chapter

4.0

**A Guide to BMP Selection and Location
in the State of Maryland**

4.0 Selecting the Best BMP at a Site

This chapter outlines a process for selecting the best BMP or group of BMPs for a development site and provides guidance on factors to consider when deciding where to locate them. The process is used to screen which BMPs can meet the pollutant removal targets for the WQ_v and guides the designer through six steps that progressively screen:

- Watershed Factors
- Terrain Factors
- Stormwater Treatment Suitability
- Physical Feasibility Factors
- Community and Environmental Factors
- Locational and Permitting Factors

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

Step ① Watershed Factors

Is the project located in a watershed that has special design objectives or constraints that must be met? Table 4.1 outlines BMP restrictions or additional design requirements that must be considered if a project lies within the Maryland Critical Area, a cold water watershed, a sensitive watershed, an aquifer protection area, a water supply reservoir, or a shellfish/beach protection zone.

Step ② Terrain Factors

Is the project located in a portion of the State that has particular design constraints imposed by local terrain and or underlying geology? Table 4.2 details BMP restrictions for regions of Maryland that have karst, mountainous terrain, or low relief.

Step ③ Stormwater Treatment Suitability

Can the BMP meet all five stormwater sizing criteria at the site or are a combination of BMPs needed? In this step, designers can screen the BMP list using Table 4.3 to determine if a particular BMP can meet the Re_v , Cp_v and/or Q_p storage requirements. In addition, Table 4.3 indicates whether a BMP is capable of treating hotspot runoff and provides comparative indexes on land consumption and safety risks that may preclude a BMP. At the end of this step, the designer can screen the BMP options down to a manageable number and determine if a single BMP or a group of BMPs is needed to meet stormwater sizing criteria at the site.

Step ④ Physical Feasibility Factors

Are there any physical constraints at the project site that may restrict or preclude the use of a particular BMP? In this step, the designer screens the BMP list using Table 4.4 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 BMP. In addition, the matrix indicates which BMP options work well in highly urban areas.

Step ⑤ Community and Environmental Factors

Do the remaining BMPs have any important community or environmental benefits or drawbacks that might influence the selection process? In this step, Table 4.5 is used to compare BMP options with regard to maintenance, habitat, community acceptance, cost and other environmental factors.

Step ⑥ Locational and Permitting Factors

What environmental features must be avoided or considered when locating the BMP system at a site to fully comply with local, State and federal regulations? In this step, the designer may use Table 4.6 as a checklist that asks whether any of the following are present at the site: wetlands, waters of the United States, stream or shoreline buffers, floodplains, forest conservation areas, and development infrastructure. Brief guidance is then provided on how to locate BMPs to avoid impacts to sensitive resources. If a BMP must be located within a sensitive environmental area, a brief summary of applicable permit requirements is provided.

Section 4.1 Watershed Factors

The design of urban BMPs is fundamentally influenced by the nature of the downstream water body that will be receiving the stormwater discharge. Consequently, designers must determine the Use Designation of the watershed in which their project is located prior to design (see COMAR 26.08.02.08 and Appendix D.9).

In some cases, higher pollutant removal or environmental performance is needed to fully protect aquatic resources and/or human health and safety within a particular watershed or receiving water. Therefore, a shorter list of BMPs may need to be considered for selection within these watersheds or zones. The areas of concern include:

Maryland Critical Area Intensely Developed Areas. BMPs located within the Intensely Developed Area (IDA) of the Maryland Critical Area (a zone extending 1000 feet landward from mean high tide and the landward edge of tidal wetlands) shall demonstrate compliance with the "10% Rule." The rule mandates that post development stormwater phosphorus loads must be reduced to 10% below pre development loads, using the methodology developed by Herson et al. (1994). For a summary review of the 10% Rule and updated estimates of long term phosphorus pollutant removal rates please consult Appendix D.4.

Coldwater Streams (Use III and IV). Cold and cool water streams have habitat qualities capable of supporting trout and other sensitive aquatic organisms. Therefore, the design objective for these streams is to maintain habitat quality by preventing stream warming, maintaining natural recharge, preventing bank and channel erosion, and preserving the natural riparian corridor. Techniques for accomplishing these objectives may include:

- Minimizing the creation of impervious surfaces,
- Minimizing surface areas of permanent pools,
- Preserving existing forested areas,
- Bypassing existing baseflow and/or springflow, or
- Providing shade-producing landscaping

Some BMPs can have adverse downstream impacts on cold water streams and their use is highly restricted.

Sensitive Streams (e.g., streams with a watershed impervious cover less than 15%). These streams may also possess high quality cool water or warm water aquatic resources. The design objectives are to maintain habitat quality through the same techniques used for cold water streams, with the exception that stream warming is not as severe of a design constraint. These streams may also be specially designated by local authorities.

Wellhead Protection. Areas that recharge existing public water supply wells present a unique management challenge. The key design constraint is to prevent possible groundwater contamination by preventing infiltration of hotspot runoff. At the same time, recharge of unpolluted stormwater is needed to maintain flow in streams and wells during dry weather.

Reservoir Protection (Use I-P, III-P and IV-P). Watersheds that deliver surface runoff to a public water supply reservoir or impoundment are of special concern. Depending on the treatment available at the water intake, it may be necessary to achieve a greater level of pollutant removal for the pollutants of concern such as bacteria pathogens, nutrients, sediment or metals. One particular management concern for reservoirs is ensuring that stormwater hotspots are adequately treated so that they do not contaminate drinking water.

Shellfish/Beach (Use II). Watersheds that drain to specific shellfish harvesting areas or public swimming beaches require a higher level of BMP treatment to prevent closings caused by bacterial contamination from stormwater runoff. In these watersheds, BMPs are explicitly designed to maximize bacteria removal.

Other Criteria. Designers should consult with the appropriate review authority to determine if their development project is subject to additional stormwater BMP criteria as a result of an adopted local watershed plan or protection zone.

Table 4.1 BMP Selection - Watershed Factors

BMP GROUP	CRITICAL AREA	COLD WATER	SENSITIVE STREAM	AQUIFER PROTECTION	RESERVOIR PROTECTION	SHELLFISH BEACH
Ponds	Drainage Area may limit except for P-5, P-1 has lower removal rates	Restricted (see Appendix B.1.2) Offline design recommended Maximize shading of open pool areas	Require additional storage for control of C _p	May require liner if A soils are present Pretreat hotspots 2-4 ft SD*	Require control of C _p	Moderate bacteria removal, design to prevent geese problems, provide permanent pools
Wetlands	Drainage area may limit, W-4 excepted	May be restricted (see Appendix B.1.2)	Require additional storage for control of C _p	May require liner if A soils are present 2-4 ft SD*	Require control of C _p	Provide 48 hr ED for max. bacterial dieoff
Infiltration	Often infeasible due to soils or water table in tidal areas.	OK, if site has appropriate soils	OK, if site has appropriate soils	SD* from wells and water table No untreated hotspot runoff OK to infiltrate rooftop runoff	SD* from bedrock and water table	OK, but a min. 2 to 4 ft SD* is required
Filtering Systems	OK	OK, but evaluate for stream warming	May be necessary for pretreatment	OK, if designed w/out exfiltration	May be necessary for pretreatment prior to another BMP	OK, Moderate to high bacterial removal
Open Channels	OK	OK	Should be linked w/basin to provide C _p	OK, but hotspot runoff must be adequately pretreated	OK, but hotspot runoff must be adequately pretreated	Poor bacterial removal for O-2

*SD = Separation Distance or distance from well or water table to BMP.

Section 4.2 Terrain Factors

Three key factors to consider are low-relief, karst and mountainous terrain. In Maryland, **Low Relief Areas** are located in the lower Eastern Shore, particularly below the Choptank River (see Figure 4.1 below). **Karst** and major carbonaceous rock areas are found in portions of Carroll, Frederick, Washington, and Garrett Counties. Mountainous areas are found in the Western part of the State. Special geotechnical testing requirements may be needed in karst areas (see Appendix D.2). The terrain regions shown on the map are approximate. Please consult with your local reviewing authority to determine if your project is subject to terrain constraints.

Figure 4.1 Map of Maryland Showing Key Terrain Factors

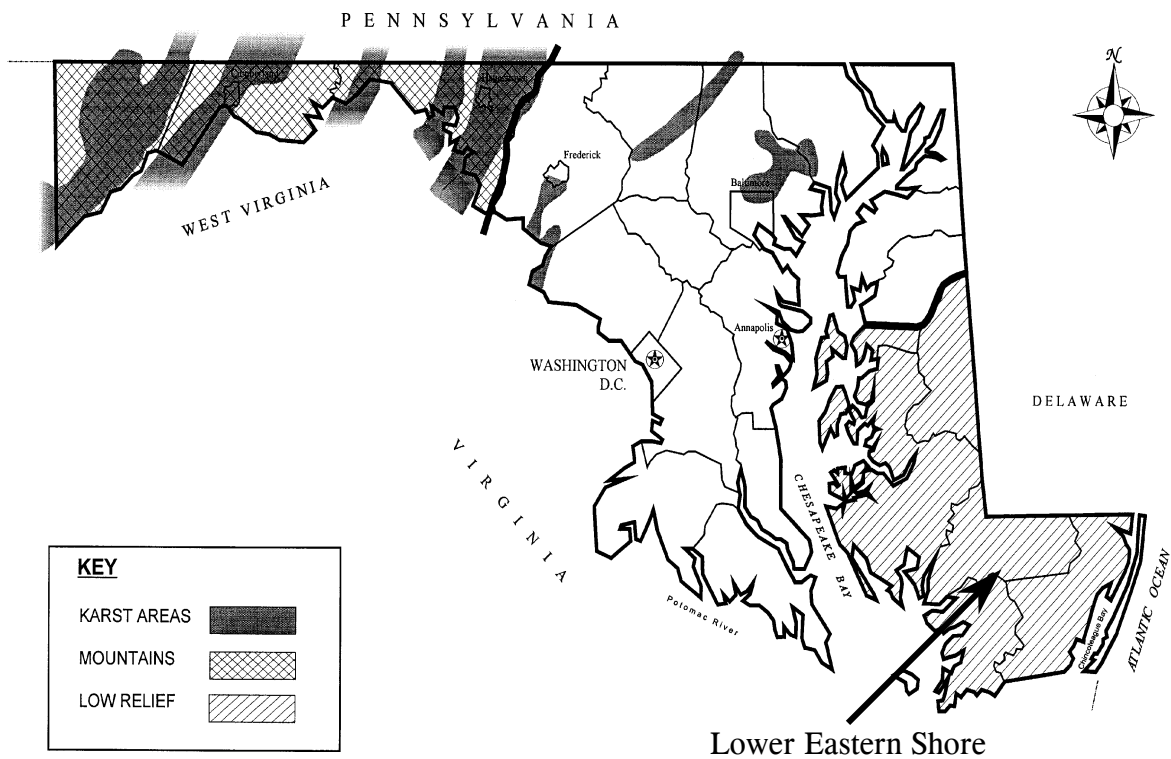


Table 4.2 BMP Selection - Terrain Factors

BMP GROUP	LOW RELIEF	KARST	MOUNTAINOUS
Ponds	Maximum normal pool depth of 4 feet (dugout)	<ul style="list-style-type: none"> • geotechnical tests • max ponding depth • Require poly or clay liner 	Embankment heights restricted
Wetlands	OK		Embankment heights restricted
Infiltration	Minimum distance to water table of 2 feet	May be prohibited. Consult with local approval authority.	Max slope 15% trenches must have flat bottom
Filtering Systems	Several designs limited by low head (F-1 and F-2)	Require poly-liner or impermeable membrane to seal bottom	OK
Open Channels	Generally feasible due to low slopes	OK	Often infeasible in steeper slopes

Section 4.3 Stormwater Treatment Suitability

Table 4.3 examines the capability of each BMP option to meet the five stormwater treatment sizing criteria outlined in Chapter 2. Thus, it shows whether a BMP has:

Ability to Meet the Re_v . It should be noted that other practices, not on the BMP list, are capable of meeting the Re_v requirement (e.g., grass channel, filter, disconnection of rooftop runoff and other practices outlined in Chapter 5). Thus, if a BMP cannot meet the Re_v requirement, supplemental practices that can provide recharge may be needed.

Ability to Provide Cp_v . The table indicates whether the BMP can typically provide the Cp_v that is needed in some watersheds. The finding that a particular BMP cannot meet the Cp_v requirement does not necessarily imply that it 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 pond).

Ability to Provide Q_{p2} and/or Q_{p10} . The table indicates whether the BMP can typically provide the Q_p criteria for the site. Again, the finding that a particular BMP 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 dry swale and a downstream pond)

Additional Safety Concerns. A comparative index expresses the potential need for additional safety features within a BMP. A “no” indicates no additional features are needed while a “yes” 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 a prime concern in many residential settings.

Adequate Space. This comparative index expresses how much space a BMP typically consumes at a site. A “yes” indicates that the BMP consumes a relatively small amount of land, whereas a “no” indicates the BMP may consume a relatively high fraction of land at the site. Again, this factor is included in this early screening stage because many BMPs are severely constrained by land consumption.

Ability to Accept Hotspot Runoff. This last column examines the capability of a BMP to treat runoff from designated hotspots as defined in Chapter 2. A BMP that receives hotspot runoff may have design restrictions as noted and may require additional measures to protect downstream resources from potential spills.

Table 4.3 BMP Selection - Stormwater Treatment Suitability

CODE	BMP List	Rev Ability	Cp Control	Qp Control	Additional Safety Concerns	SPACE	ACCEPT HOTSPOT RUNOFF
P-1	Micropool ED	No ¹	Yes	Yes	No	Yes	Yes ³
P-2	Wet Pond	No ¹	Yes	Yes	Yes	Varies	Yes ³
P-3	Wet ED Pond	No ¹	Yes	Yes	Yes	Yes	Yes ³
P-4	Multiple Pond	No ¹	Yes	Yes	Yes	No	Yes ³
P-5	Pocket Pond	No ¹	Yes	Yes	Varies	Yes	Yes ³
W-1	Shallow Wetland	Varies ²	Yes	Yes	No	No	Yes ³
W-2	ED Wetland	Varies ²	Yes	Yes	Varies	Varies	Yes ³
W-3	Pond/Wetland	Varies ²	Yes	Yes	Yes	No	Yes ³
W-4	Pocket Wetland	No	Varies	Varies	No	Varies	Yes ³
I-1	Infiltration Trench	Yes	Varies	Varies	No	Yes	No ³
I-2	Infiltration Basin	Yes	Varies	Varies	No	Varies	No ³
F-1	Surface Sand Filter	Varies ²	Varies	Varies	No	Yes	Yes ⁴
F-2	Underground SF	No	No	No	Varies	Yes	Yes
F-3	Perimeter SF	No	No	No	No	Yes	Yes
F-4	Organic Filter	Varies ²	Varies	Varies	No	Yes	Yes ⁴
F-5	Pocket Sand Filter	Varies ²	Varies	Varies	No	Yes	Yes ⁴
F-6	Bioretention	Yes	Varies	Varies	No	Varies	Yes ⁴
O-1	Dry Swale	Yes	No	No	No	Varies	Yes ⁴
O-2	Wet Swale	No	No	No	No	Varies	No
<p>1 Structures that require impermeable liners or that intercept groundwater may not be used for groundwater recharge.</p> <p>2 Rev may be provided by exfiltration (see Chapter 3.4).</p> <p>3 Not allowed unless pretreatment to remove hydrocarbons, trace metals, and toxicants is provided.</p> <p>4 Yes, but only if bottom of facility is lined with impermeable filter fabric that prevents leachate infiltration.</p>							

Section 4.4 Physical Feasibility Factors

At this point, the designer has narrowed the BMP list to a manageable size and can evaluate the remaining options given the physical conditions at a site. This table cross-references testing protocols needed to confirm physical conditions at the site. The six primary factors are:

Soils. The key evaluation factors are based on an initial investigation of the USDA 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 (see Appendix D.1).

Water Table. This column indicates the minimum depth to the seasonally high water table from the bottom or floor of a BMP.

Drainage Area. This column indicates the recommended minimum or maximum drainage area that is considered suitable for the practice. If the drainage area present at a site is slightly greater than the maximum allowable drainage area for a practice, some leeway is permitted or more than one practice can be installed. The minimum drainage areas indicated for ponds and wetlands are flexible depending on water availability (baseflow or groundwater) or the mechanisms employed to prevent clogging.

Slope Restriction. This column evaluates the effect of slope on the practice. Specifically, the slope restrictions refer to how flat the area where the practice may be.

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

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

Table 4.4 BMP Selection - Physical Feasibility

CODE	BMP LIST	SOILS	WATER TABLE	DRAINAGE AREA (Acres)	SLOPE RESTRICT.	HEAD (Ft)	ULTRA URBAN
P-1	Micropool ED	"A" Soils May Require Pond Liner "B" Soils May Require Testing	4 Feet ¹ If Hotspot Or Aquifer	10 Min ²	None	6 to 8 Ft	Not Practical
P-2	Wet Pond			25 Min ²			
P-3	Wet ED Pond						
P-4	Multiple Pond			5 Max ³		4 Ft	
P-5	Pocket Pond	OK	Below WT	5 Max ³		4 Ft	OK
W-1	Shallow Wetland	"A" Soils May Require Liner	4 Feet ¹ If Hotspot Or Aquifer	25 Min	None	3 to 5 Ft	Not Practical
W-2	ED Wetland						
W-3	Pond/Wetland						
W-4	Pocket Wetland	OK	Below WT	5 Max		2 To 3 Ft	Depends
I-1	Infiltration Trench	$f \geq 0.52$ Inch/Hr	4 Feet ¹	5 Max	Installed in No More Than 15% Slopes	1 Ft	Depends
I-2	Infiltration Basin			10 Max		3 Ft	Not Practical
F-1	Surface Sand Filter	OK	2 Feet	10 Max ³	None	5 Ft	Depends
F-2	Underground SF			2 Max ³		5 to 7ft	OK
F-3	Perimeter SF			2 Max ³		2 to 3 Ft	
F-4	Organic Filter			5 Max ³		2 to 4 Ft	
F-5	Pocket SF			5 Max ³		2 to 5 Ft	
F-6	Bioretention					Made Soil	
O-1	Dry Swale	Made Soil	2 Feet	5 Max	4% Max Cross-slope	3 to 5 Ft	Not Practical
O-2	Wet Swale	OK	Below WT	5 Max		1 Ft	

Notes: OK= not restricted, WT= water table

- 1** Four foot separation distance is maintained to the seasonally high water table (2 feet on Lower Eastern Shore).
- 2** Unless adequate water balance and anti-clogging device installed
- 3** Drainage area can be larger in some instances

Section 4.5 Community and Environmental Factors

The fifth step assesses community and environmental factors involved in BMP selection. This table employs a comparative index approach indicating whether the BMP has a high or low benefit.

Ease of Maintenance. This column assesses the relative maintenance effort needed for a BMP 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 BMPs** 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 aesthetics. It should be noted that a low rank can often be improved by a better landscaping plan.

Construction Cost. The BMPs are ranked according to their relative construction cost per impervious acre treated as determined from cost surveys and local experience.

Habitat Quality. BMPs 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 BMP and its buffer.

Other Factors. This column indicates other considerations in BMP selection.

Table 4.5 BMP Selection - Community and Environmental Factors

CODE	BMP LIST	EASE OF MAINTENANCE	COMMUNITY ACCEPTANCE	COST (Relative To Drainage Area)	HABITAT QUALITY	OTHER FACTORS
P-1	Micropool ED	Medium	Medium	Low	Medium	Trash/debris
P-2	Wet Pond	Easy	High	Low	High	
P-3	Wet ED Pond	Easy	High	Low	High	
P-4	Multiple Pond	Easy	High	Medium	High	
P-5	Pocket Pond	Difficult	Medium	Low	Low	Drawdowns
W-1	Shallow Wetland	Medium	High	Medium	High	
W-2	ED Wetland	Medium	Medium	Medium	High	Limit ED depth
W-3	Pond/Wetland	Difficult	High	Medium	High	
W-4	Pocket Wetland	Medium	Low	Low	Medium	Drawdowns
I-1	Infiltration Trench	Difficult	High	Medium	Low	Avoid large stone
I-2	Infiltration Basin	Medium	Low	Medium	Low	Frequent pooling
F-1	Surface SF	Medium	Medium	High	Low	
F-2	Underground SF	Difficult	High	High	Low	Underground ∴ Out of sight
F-3	Perimeter SF	Difficult	High	High	Low	Traffic Bearing
F-4	Organic Filter	Medium	High	High	Low	Filter Media Replacement
F-5	Pocket SF	Medium	Medium	Medium	Low	
F-6	Bioretention	Medium	Medium	Medium	Low	Landscaping
O-1	Dry Swale	Easy	High	Medium	Low	
O-2	Wet Swale	Easy	High	Low	Low	Mosquitoes Possible

Section 4.6 Checklist: Location and Permitting Factors

In the last step, a designer assesses the physical and environmental features at the site to determine the optimal location for the selected BMP or group of BMPs. The checklist below provides a condensed summary of current BMP restrictions as they relate to common site features that may be regulated under local, State or federal law. These restrictions fall into one of three general categories:

1. Locating a BMP within an area that is expressly **prohibited** by law.
2. Locating a BMP within an area that is **strongly discouraged** and is only allowed on a case by case basis. Local, State and/or federal permits shall be obtained and the applicant will need to supply additional documentation to justify locating the BMP within the regulated area.
3. BMPs must be **setback** a fixed distance from the site feature.

This checklist is only intended as a general guide to location and permitting requirements as they relate to siting stormwater BMPs. Consultation with the appropriate regulatory agency is the best strategy.

The symbol “✓” denotes when an MDE Nontidal Wetland And Waterways Permit shall be obtained.

Table 4.6 Location and Permitting Factors Checklist

SITE FEATURE	LOCATION AND PERMITTING GUIDANCE
<p><input type="checkbox"/> Jurisdictional Wetland</p> <p>U.S. Army Corps of Engineers Section 404 Permit</p> <p>and/or</p> <p>MDE Wetlands Permit ✓</p>	<ul style="list-style-type: none"> • wetlands should be delineated prior to siting stormwater BMPs. • use of wetlands for stormwater treatment strongly discouraged and requires State and federal permit. • BMPs are also restricted in the 25 to 100 foot required wetland buffer. • buffers may be utilized as a non-structural filter strip (e.g., accept sheetflow). • must justify that no practical upland treatment alternatives exist. • stormwater must be treated prior to discharge into a wetland. • where practical, excess stormwater flows should be conveyed away from jurisdictional wetlands.
<p><input type="checkbox"/> Stream Channel (Waters of the U.S)</p> <p>U.S. Army Corps of Engineers (COE) Section 404 Permit</p> <p>MDE Wetlands and Waterways Permit ✓</p>	<ul style="list-style-type: none"> • stream channels should be delineated prior to design using MDE criteria. • instream ponds require MDE review and permit. • instream ponds are prohibited in Use III waters. • ponds located within USE III watersheds may require small pond review and approval from the MDE Dam Safety Division. • must justify that no practical upland treatment alternatives exist. • Q_p and C_{pv} treatment is preferred over WQ_v treatment. • implement measures that reduce downstream warming.
<p><input type="checkbox"/> 100 Year Floodplain</p> <p>Local Stormwater review Authority</p> <p>MDE Wetlands and Waterways Permit ✓</p>	<ul style="list-style-type: none"> • grading and fill for BMP construction is strongly discouraged within the ultimate 100 year floodplain, as delineated by FEMA flood insurance rate, FEMA flood boundary and floodway, or local floodplain maps. • floodplain fill cannot raise the floodplain water surface elevation by more than a tenth of a foot.
<p><input type="checkbox"/> Stream Buffer</p> <p>Check with appropriate review authority whether stream buffers are required</p>	<ul style="list-style-type: none"> • consult local authority for stormwater policy. • ponds located within 100 feet of a flowing stream in a USE III watershed may require a small pond approval by the MDE Dam Safety Division • BMPs are strongly discouraged in the stream-side zone (within 25 feet of streambank). • consider how outfall channel will cross buffer to reach stream. • BMPs can be located within the outer portion of a buffer.

Table 4.6 Location and Permitting Factors Checklist (Continued)

SITE FEATURE	LOCATION AND PERMITTING GUIDANCE
<input type="checkbox"/> Forest Conservation District Forest Conservation Review Authority	<ul style="list-style-type: none"> • BMPs are strongly discouraged within Priority 1 Forest Retention Areas. • BMPs must be setback at least 25 feet from the critical root zone of specimen trees, or • designers should consider the effect of more frequent inundation for Q_p, C_p and WQ_v on existing forest stands. • BMP buffer areas are acceptable as reforestation sites if they are protected by a conservation agreement
<input type="checkbox"/> Critical Area Local Critical Area Review Authority	<ul style="list-style-type: none"> • BMPs w/in the Critical Area shoreline buffer are prohibited unless a variance is obtained from the local review authority. • BMPs are acceptable within mapped buffer exemption areas. • BMPs in the IDA must meet the 10% Rule - see Appendix D.4.
<input type="checkbox"/> Utilities Local Review Authority	<ul style="list-style-type: none"> • call Miss Utility to locate existing utilities prior to design. • note the location of proposed utilities to serve development. • BMPs are discouraged within utility easements or rights of way for public or private utilities.
<input type="checkbox"/> Roads Local DOT, DPW, or State Highway Administration	<ul style="list-style-type: none"> • consult local DOT or DPW for any setback requirement from local roads. • consult SHA for setbacks from State maintained roads. • approval must also be obtained for any stormwater discharges to a local or State-owned conveyance channel.
<input type="checkbox"/> Structures Local Review Authority	<ul style="list-style-type: none"> • consult local review authority for BMP setbacks from structures. • recommended <i>setbacks</i> for each BMP group are provided in the performance criteria in Chapter 3 of this manual.
<input type="checkbox"/> Septic Drain fields	<ul style="list-style-type: none"> • consult local health authority. • recommended setback is a minimum of 50 feet from drain field edge.
<input type="checkbox"/> Water Wells Local Health Authority	<ul style="list-style-type: none"> • 100 foot setback for stormwater infiltration. • 50 foot setback for all other BMPs. • water appropriation permit needed if well water used for water supply to a BMP.
<input type="checkbox"/> Sinkholes	<ul style="list-style-type: none"> • infiltration or pooling of stormwater near sinkholes is prohibited. • geotechnical testing may be required within karst areas (see Appendix D.2).