CHAPTER

4

DESIGN AND MAINTENANCE OF STRUCTURAL BMPS

Structural stormwater best management practices (BMPs) are engineered facilities that are intended to treat stormwater runoff and/or mitigate the effects of increased stormwater runoff peak discharge, volume, and velocity due to urbanization. This chapter provides detailed descriptions and design specifications for the structural stormwater BMPs that can be used to address Knox County's minimum stormwater management standards outlined in Chapter 1 and the design criteria cited in Chapter 3.

In terms of the Integrated Site Design approach, a structural stormwater BMP, or a series of structural BMPs, must:

- Treat the Water Quality Volume (WQv);
- Control the Channel Protection Volume (CPv);
- Control for Overbank Flood Protection (up to Qp_{25}), and
- Provide for Extreme Flood Protection (Qp_{100}).

4.1 Design Standards Policy

The State of Tennessee's NPDES Phase II regulation requires that Knox County implement a post-construction stormwater treatment program for all new developments and redevelopments. To comply with this regulation, the Stormwater Management Ordinance requires that stormwater runoff be treated for pollutants prior to discharge from the site. Further, Knox County policy established in Chapters 1 and 3 (Volume 2) of this manual sets the minimum design standard for stormwater treatment as removal of 80% of the average annual post-development total suspended solids (TSS) load. The structural BMPs presented in this chapter of the Knox County stormwater management manual, used alone or in series, can be used to meet this minimum design standard. For purposes of compliance with local and State regulations, it is presumed that developments and redevelopments are meeting the 80% TSS removal standard so long as stormwater management systems are designed, constructed, and maintained in accordance with the design criteria and specifications discussed in this manual.

Therefore, Knox County requires that all of the structural BMPs presented in this section be designed, constructed and maintained in accordance with the criteria, standards, and specifications presented in the stormwater management ordinance and in this manual.

Proprietary, new, and other BMPs not included in this manual may be approved by the Director of Engineering and Public Works (Director) for treatment of stormwater quality on a case-by-case basis provided that the conditions outlined in Volume 2, Section 2.2.2.1 of this manual are met.

4.2 BMP Description and Selection Information

The structural stormwater BMPs recommended in this manual have been placed into two categories, general application and limited application, based upon generalized acceptance criteria set by Knox County Engineering. These categories are described below.

4.2.1 General Application BMPs

A listing of general application BMPs can be found in Table 4-1 below. Knox County will accept these BMPs for use with a wide variety of land uses and development types. General application BMPs have a demonstrated ability to treat the WQv and many are presumed to be able to achieve the 80% TSS removal standard when designed, constructed and maintained in accordance with recommended specifications. Several of the general application BMPs can also be designed to comply with other stormwater criteria, for downstream channel protection, and overbank and extreme flood protection. Knox County recommends that general application BMPs be utilized for the stormwater management facilities for a site wherever feasible and practical. A detailed discussion of each of the general application BMPs, as well as design criteria and procedures can be found later in this chapter.

Table 4-1. Descriptions of General Application BMPs

Structural BMP	Description
Stormwater Ponds • Wet Pond • Wet ED Pond • Micropool ED Pond • Multiple Pond Systems	Stormwater ponds are constructed stormwater retention basins that have a permanent pool (or micropool) of water. Runoff from each rain event is detained and treated in the pool. ED = Extended Detention. ED is the detention of stored runoff for a minimum of 24 hours.
Detention Basins • Dry Detention Basin • Dry ED Basin	Dry detention basins and dry extended detention (ED) basins are surface facilities intended to provide for the temporary storage of stormwater runoff to reduce downstream water quantity impacts and will have to be combined with another BMP to achieve the 80% TSS removal goal.
Stormwater Wetlands • Shallow Wetland • ED Shallow Wetland • Pond/Wetland Systems • Pocket Wetland	Stormwater wetlands are constructed wetland systems used for stormwater management. Stormwater wetlands consist of a combination of shallow marsh areas, open water and semi-wet areas above the permanent water surface.
Bioretention Areas	Bioretention areas are shallow stormwater basins or landscaped areas which utilize engineered soils and vegetation to capture, infiltrate and treat stormwater runoff. Runoff may be returned to the conveyance system, or allowed to partially infiltrate into the soil.
Sand Filters • Surface Sand Filter • Perimeter Sand Filter	Sand filters are multi-chamber structures designed to treat stormwater runoff through filtration, using a sand bed as its primary filter media. Filtered runoff may be returned to the conveyance system, or allowed to partially infiltrate into the soil.
Infiltration Trench	An infiltration trench is an excavated trench filled with stone aggregate used to capture and allow infiltration of stormwater runoff into the surrounding soils from the bottom and sides of the trench.
Enhanced Swales • WQ Dry Swale • Wet Swale	Enhanced swales are vegetated open channels that are explicitly designed and constructed to capture and treat stormwater runoff within dry or wet cells formed by check dams or other means.

Structural BMP	Description
Biofilters • Filter Strip • Grass Channel	Both filter strips and grass channels provide "biofiltering" of stormwater runoff as it flows across the grass surface. However, by themselves these controls cannot meet the 80% TSS removal performance goal. Consequently, both filter strips and grass channels should only be used as pretreatment measures or as part of a treatment train approach. Grass channels are open channel practices that are not designed specifically for water quality.
Modular Porous Paver Systems and Porous Pavement/Concrete	Porous surfaces are permeable pavement surfaces with an underlying stone reservoir to temporarily store surface runoff before it infiltrates into the subsoil. These practices are considered source control BMPs rather than treatment BMPs. Areas where porous surfaces have been applied are included in the WQv calculations as pervious surfaces, rather than impervious surfaces. Porous concrete is the term for a mixture of course aggregate, portland cement and water that allows for rapid infiltration of water. Modular porous paver systems consist of open void paver units laid on a gravel subgrade. Both porous concrete and porous paver systems provide water quality and quantities benefits, but may have high workmanship and maintenance requirements.

4.2.2 Limited Application BMPs

Limited application BMPs will be allowed only when the use of general application BMPs is not feasible because special site or design conditions prohibit their use. Limited application BMPs will be approved for use in Knox County on a site-by-site basis. In general, limited application BMPs are intended to address hotspot or specific land use constraints or conditions requiring pretreatment, and may have high installation costs or special maintenance requirements that may preclude their use for most general applications. Limited application BMPs are typically used for water quality treatment only and do not provide additional control for channel or flood protection. Limited application BMPs should be considered primarily for commercial, industrial or institutional developments.

Table 4-2 lists the limited application BMPs, along with the rationale for limited use. These structural BMPs are recommended for use with particular land uses and densities, to meet certain water quality requirements, for limited usage on larger projects, or as part of a stormwater treatment train. A detailed discussion of each of the limited application BMPs, as well as design criteria and procedures can be found later in this chapter.

4.2.3 Pollutant Removal Capabilities

Research has shown that the use of the structural BMPs discussed in this chapter will have benefits for the removal of TSS and other pollutants (i.e., phosphorous, nitrogen, fecal coliform and heavy metals). The ability for both general and limited application BMPs to remove pollutants varies by structural BMP type and by pollutant type. Pollutant removal capabilities for a given BMP are based on a number of factors including the physical, chemical and/or biological processes that take place in the BMP and the design and sizing of the facility. In addition, pollutant removal efficiencies for the same BMP type and facility design can vary widely depending on the tributary land use and area, incoming pollutant concentration, rainfall pattern, time of year, maintenance frequency and numerous other factors.

Table 4-2. Descriptions of Limited Application BMPs

Structural BMP	Description and Rationale for Limited Use
Filtering Practices • Organic Filter	Organic filters are surface sand filters where organic materials such as a leaf compost or peat/sand mixture are used as the filter media. These media may be able to provide enhanced removal of some contaminants, such as heavy metals and nutrients. Given their potentially high maintenance requirements, they should only be used in environments that warrant their use.
• Underground Sand Filter	Underground sand filters are sand filter systems located in an underground vault. These systems should only be considered for extremely high density or space-limited sites.
Wetland Systems • Submerged Gravel Wetlands	Submerged gravel wetlands systems use wetland plants in a submerged gravel or crushed rock media to remove stormwater pollutants. These systems should only be used in mid- to high-density environments where the use of other structural controls may be precluded. The long-term maintenance burden of these systems is uncertain.
Chemical Treatment • Alum Treatment	Alum treatment provides for the removal of suspended solids from stormwater runoff entering a wet pond by injecting liquid alum into the stormwater system. Alum treatment should only be considered for large-scale projects where high water quality is desired and where other BMPs do not provide the level of pollutant removal required for the receiving water.
Proprietary Systems • Commercial Stormwater BMPs	Proprietary BMPs are manufactured structural control systems available from commercial vendors designed to improve stormwater runoff quality and/or provide water quantity control. Proprietary systems often can be used on small sites and in space-limited areas, as well as in pretreatment applications. However, proprietary systems are often more costly than other alternatives, may have high maintenance requirements, and often lack adequate independent performance data, particularly for use in Knox County conditions. Approval of the Knox County Engineering and Public Works Director is required prior to their implementation.
Gravity (oil-grit) Separator	Gravity separators, (also called hydrodynamic BMPs) use the movement of stormwater runoff through a specially designed structure to remove target pollutants. They are typically used on smaller impervious commercial sites and urban hotspots. These BMPs typically do not meet the 80% TSS removal performance goal, and therefore, should only be used as a pretreatment measure and as part of a treatment train approach.

Table 4-3 provides design removal efficiencies assigned to each of the general and limited application BMPs. It should be noted that these values are median pollutant reduction percentages for design purposes that have been derived from existing sampling data, modeling and research. A structural BMP design may be capable of exceeding these performances; however, the values in the table are considered median values that can be assumed to be achieved when the structural BMP is sized, designed, constructed and maintained in accordance with recommended specifications in this manual.

Where the pollutant removal capabilities of an individual structural stormwater BMP are not sufficient for a given site application, additional controls may be used in series in a "treatment train" approach. More detail on the use of stormwater BMPs in series is provided later in this chapter.

Table 4-3. Design Pollutant Removal Efficiencies (in %) for Structural BMPs

Structural BMP	TSS	Total P[1]	Total N[2]	Fecal Coliform	Metals
General Application Structural BMPs					
Stormwater Ponds (Wet ED Pond, Micropool ED Pond, and Multiple Pond Systems)	80	55	30	70*	50
Conventional Dry Detention Pond	10	---	---	---	---
Dry Extended Detention Pond	60	35	25	---	25
Stormwater Wetlands (Shallow Wetlands, ED Wetlands, Pond/Wetland System, Pocket Wetland)	75	45	30	70*	50
Bioretention Areas	85	60	50	---	80
Sand Filters	80	50	30	40	50
Infiltration Trench	90	60	60	90	90
Water Quality (WQ) Dry Swale	90	50	50	---	40
Wet Swale	75	25	40	---	20
Filter Strip	50	20	20	---	40
Grass Channel[3]	30	25	20	---	30
Modular Porous Paver Systems and Porous Pavement/Concrete	**	**	**	**	**
Limited Application Structural BMPs					
Organic Filter	80	60	40	50	75
Underground Sand Filter	80	50	25	40	50
Submerged Gravel Wetland	80	50	20	70	50
Alum Treatment	90	80	60	90	75
Proprietary Systems	***	***	***	***	***
Gravity (oil-grit) Separator	30	5	5	---	---

1 Total phosphorus
2 Total nitrogen
3 Refers to open channel practices not designed specifically for water quality.
* If no resident waterfowl population is present.
** These practices are source controls and are not designed as pollutant removal devices.
*** The performance of specific proprietary commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data.
--- Insufficient data to provide design removal efficiency. See Volume 2, Section 2.2.2.1 for details.

4.2.4 Screening Process for General Application BMPs

Outlined below is a process used in the selection of general application BMPs. This process is intended to assist the site developer and design engineer in determining the most appropriate structural BMP for a development site, and to provide guidance on factors to consider in their location. Knox County's goal of 80% TSS removal is the primary factor in the selection process of BMPs or BMP treatment trains. Information on selection factors related to pollutants other than TSS is provided for informational purposes, and may be useful in the future depending upon local, state and federal water quality regulations at that time.

In general, the following four criteria should be evaluated in order to select the appropriate structural BMP(s) or group of BMPs for a development:

- stormwater treatment suitability;
- water quality performance;
- site applicability;
- implementation considerations.

In addition, for a given site, the following factors should be considered and any specific design criteria or restrictions need to be evaluated:

- physiographic factors;
- soils;
- special watershed or stream considerations.

Finally, environmental regulations that may influence the location of a structural BMP on site, or may require a permit, need to be considered.

Guidance on a selection process for comparing and evaluating various general application structural stormwater BMPs using two screening matrices and a list of location and permitting factors is presented below. These tools are provided to assist the design engineer in selecting the subset of structural BMPs that will meet the stormwater management and design objectives for a development site or project.

Step 1: Evaluate Overall Applicability

Through the use of Table 4-4, the site designer evaluates and screens the overall applicability of the full set of general application structural BMPs as well as the constraints of the site in question. The discussion following the table presents an explanation of the various screening categories and individual characteristics used to evaluate the structural BMPs.

Stormwater Management Suitability

The first columns of Table 4-4 examine the capability of each structural BMP option to provide water quality treatment, downstream channel protection, overbank flood protection, and extreme flood protection. A blank entry means that the structural BMP cannot or is not typically used to meet the aforementioned criteria. This does not necessarily mean that it should be eliminated from consideration, but rather is a reminder that more than one structural BMP may be needed at a site (e.g., a bioretention area used in conjunction with dry detention storage).

> *Ability to treat the Water Quality Volume (WQv).* This indicates whether a structural BMP provides treatment of the WQv and provides the TSS reduction amount assigned to each BMP type.

Table 4-4. General Application BMP Screening Matrix – Overall BMP Applicability

STRUCTURAL BMP CATEGORY	STRUCTURAL BMP	STORMWATER TREATMENT SUITABILITY				WATER QUALITY PERFORMANCE*		SITE APPLICABILITY					IMPLEMENTATION CONSIDERATIONS			
		Water Quality	Channel Protection	Overbank Flood Protection	Extreme Flood Protection	TSS / Sediment Removal Rate	Hotspot Application	Drainage Area (acres)	Space Req'd (% of tributary imp. Area)	Site Slope	Minimum Head Required	Depth to Water Table	Residential Subdivision Use	High Density / Ultra-Urban	Capital Cost	Maintenance Burden
Stormwater Ponds	Wet Pond	✓	✓	✓	✓	80%		25 min**	2-3%	15% max	6 to 8 ft	2 feet, if hotspot or aquifer	✓		Low	Low
	Wet ED Pond	✓	✓	✓	✓								✓		Low	Low
	Micropool ED Pond	✓	✓	✓	✓			10 min**					✓		Low	Moderate
	Multiple Ponds	✓	✓	✓	✓			25 min**					✓		Low	Low
Detention Basins	Extended Detention	✓	✓	✓	✓	60%		any	4-5%	15% max		2 feet min	✓		Low	Low
	Conventional Detention	✓	✓	✓	✓	10%		any	4-5%	15% max		2 feet min	✓		Low	Low
Stormwater Wetlands	Shallow Wetland	✓	✓	✓	✓	75%		25 min	3-5%	8% max	3 to 5 ft	2 feet, if hotspot or aquifer	✓		Moderate	Moderate
	Shallow ED Wetland	✓	✓	✓	✓								✓		Moderate	Moderate
	Pond/Wetland	✓	✓	✓	✓						6 to 8 ft		✓		Moderate	Moderate
	Pocket Wetland	✓	✓					5 min			2 to 3 ft	below WT	✓	✓	Moderate	High
Bioretention	Bioretention Areas	✓	♦			85%		5 max***	5%	6% max	5 ft	2 feet	✓	✓	Moderate	Moderate
Sand Filters	Surface Sand Filter	✓	♦			80%	✓	10 max***	2-3%	6% max	5 ft	2 feet		✓	High	High
	Perimeter Sand Filter	✓	♦				✓	2 max***			2 to 3 ft			✓	High	High
Infiltration	Infiltration Trench	✓	♦			90%		5 max	2-3%	6% max	1 ft	4 feet	✓	✓	High	High
Enhanced Swales	Dry Swale	✓	♦			90%		5 max	10-20%	4% max	3 to 5 ft	2 feet	✓		Moderate	Low
	Wet Swale	✓	♦			75%		5 max			1 ft	below WT	✓		High	Low
Biofilters	Filter Strip	✓				50%		2 max	20-25%	2-6% max		2-4 feet	✓		Low	Moderate
	Grass Channel	✓				30%		5 max	10-20%	4% max		2 feet	✓		Low	Low
Modular Porous Paver Systems and Porous Pavement/Concrete	Porous Pavers, Pavement and Concrete		✓			**		5 max	varies	5%	2 ft	4 feet	✓	✓	Moderate	High

✓ This BMP meets suitability criteria.

♦ This BMP can be incorporated into the structural control in certain situations.

* TSS pollutant removal rates must be used for design purposes. See Volume 1 Chapter 3 for guidance on calculating the % TSS removal for a development site.

** Smaller drainage areas may be approved by the Director with adequate water balance and anti-clogging device.

*** The use of this BMP for larger drainage areas may be approved by the Director if design calculations show that the BMP will achieve its design intentions given a larger drainage area.

Ability to provide Channel Protection (CPv). This indicates whether the structural BMP can be used to provide the extended detention of the CPv. The presence of a check mark indicates that the structural control can be used to meet CPv requirements. A diamond indicates that the structural control may be sized to provide channel protection in certain situations, for instance on small sites.

Ability to provide Overbank Flood Protection (Qp_{25}). This indicates whether a structural BMP can be used to meet the overbank flood protection criteria. The presence of a check mark indicates that the structural control can be used to provide peak reduction of the 25-year storm event.

Ability to provide Extreme Flood Protection (Qp_{100}). This indicates whether a structural BMP can be used to meet the extreme flood protection criteria. The presence of a check mark indicates that the structural control can be used to provide peak reduction of the 100-year storm event.

Relative Water Quality Performance

The second group of columns in Table 4-4 provides an overview of the pollutant removal performance of each structural control option, when designed, constructed and maintained according to the criteria and specifications in this manual.

Ability to provide TSS Removal. This column indicates the capability of a structural BMP to remove TSS from runoff.

Ability to provide Nutrient Treatment. This column indicates the capability of a structural BMP to remove the nutrients nitrogen and phosphorus in runoff, which may be of particular concern with certain downstream receiving waters.

Ability to provide Bacteria Removal. This column indicates the capability of a structural BMP to remove bacteria in runoff. This capability may be of particular focus in designated recreation areas with public beaches or to meet future water regulatory quality criteria under the Total Maximum Daily Load (TMDL) program.

Ability to accept Hotspot Runoff. This last column indicates the capability of a structural BMP to treat runoff from designated hotspots. Hotspots are land uses or activities with higher potential pollutant loadings. Examples of hotspots might include: gas stations, convenience stores, marinas, public works storage areas, vehicle service and maintenance areas, commercial nurseries, and auto recycling facilities. A check mark indicates that the structural BMP may be used on hotspot site, however it may have specific design restrictions. Please see Section 4.3 for the specific design criteria of the structural BMP for more details.

Site Applicability

The third group of columns in Table 4-4 provides an overview of the specific site conditions or criteria that must be met for a particular structural BMP to be suitable. In some cases, these values are recommended values or limits that can be exceeded or reduced with proper design or depending on specific circumstances. Refer to the specific criteria section of the structural BMP in Section 4.2 for more details.

Drainage Area. This column indicates the approximate minimum or maximum drainage area that is considered suitable for the structural BMP. The Director may approve exceptions to the drainage area maximum or minimum depending on the site conditions and the structural BMP(s) being proposed. The 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), the mechanisms employed to prevent outlet clogging, or design variations used to maintain a permanent pool (e.g., liners).

Space Required (Space Consumed). This comparative index expresses how much space a structural BMP typically consumes at a site in terms of the approximate area required as a percentage of the area draining to the control.

Slope. This column evaluates the effect of slope on the structural BMP. Specifically, the slope restrictions refer to how flat the area where the facility is installed must be and/or how steep the contributing drainage area or flow length can be.

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

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

Implementation Considerations

The last group of columns of Table 4-4 provides additional considerations for the applicability of each structural BMP option.

Residential Subdivision Use. This column identifies whether or not a structural BMP is suitable for typical residential subdivision development (not including high-density or ultra-urban areas).

Ultra-Urban. This column identifies those structural BMPs that are appropriate for use in very high-density (ultra-urban) areas, or areas where space is a premium.

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

Maintenance. This column assesses the relative maintenance effort needed for a structural stormwater 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 structural BMPs require routine inspection and maintenance.

Step 2: Specific Criteria

Table 4-5 provides an overview of various design criteria and specifications, or exclusions for a structural BMP that may be present due to a site's general physiographic character, soils, or location in a watershed with special water resources considerations.

Physiographic Factors

Three key factors to consider are low-relief, high-relief, and karst terrain. In Knox County, low relief (very flat) areas and high relief (steep and hilly) areas are found throughout the county. Karst and major carbonaceous rock areas are found throughout portions of Knox County. Special geotechnical testing requirements may be needed in karst areas. Knox County Engineering should be consulted to determine if a project is subject to terrain constraints.

- Low relief areas need special consideration because many structural BMPs require a hydraulic head to move stormwater runoff through the facility.
- High relief areas may limit use of some structural BMPs that need flat or gently sloping areas to settle out sediment or to reduce velocities. In other cases high relief may impact embankment heights to the point that a structural BMP becomes infeasible.
- Karst areas can limit the use of some structural BMPs as the infiltration of polluted waters directly into underground streams found in karst areas may be prohibited. In addition, ponding areas may not reliably hold water in karst areas.

Table 4-5. General Application BMP Screening Matrix – Specific Criteria

STRUCTURAL BMP	PHYSIOGRAPHIC FACTORS			SOILS
	Low Relief	High Relief	Karst	
Stormwater Ponds	Limit maximum normal pool depth to about 4 feet (dugout) Providing pond drain can be problematic	Embankment height restrictions	Require poly or clay liner Max ponding depth Geotechnical tests	"A" soils may require pond liner "B" soils may require infiltration testing
Detention Basins	✸	Embankment height restrictions	Require poly or clay liner Max ponding depth Geotechnical tests	"A" soils may require pond liner "B" soils may require infiltration testing
Stormwater Wetlands	✸	Embankment height restrictions	Require poly-liner Geotechnical tests	"A" soils may require pond liner
Bioretention & Sand Filters	Several design variations will likely be limited by low head	✸	Use poly-liner or impermeable membrane to seal bottom	Clay or silty soils may require pretreatment
Infiltration	Minimum distance to water table of 2 feet	Maximum slope of 6% Trenches must have flat bottom	Generally not allowed	Infiltration rate > 0.5 inch/hr
Enhanced Swales	Generally feasible however slope <1% may lead to standing water in dry swales	Often infeasible if slopes are 4% or greater	✸	✸
Biofilters (Filter Strips & Grass Channels)	✸	✸	✸	✸
Modular Pavers/Porous Pavement	✸	Maximum slope of 5%	✸	Underdrain system required for C and D soils

✸ - These BMPs typically have no limiting factors or constraints for physiographic factors or soils.

Soils

The key evaluation factors are based on an initial investigation of the Natural Resources Conservation Service (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.

Additionally, the design of structural stormwater controls is fundamentally influenced by the nature of the downstream water body that will be receiving the stormwater discharge. 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. Special design criteria for a particular structural control or the exclusion of one or more controls may need to be considered within these watersheds or areas. An important watershed factor to consider is the protection of drinking water sources, wellheads and surface reservoirs. 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 encouraged to maintain flow in streams and wells during dry weather. Watersheds that deliver surface runoff to a public water supply reservoir or impoundment are a special concern also. 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.

Step 3: Location and Permitting Considerations

In the last step, a site designer assesses the physical and environmental features at the site to determine the optimal location for the selected structural BMP or group of BMPs. Table 4-6 provides a condensed summary of current 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:

- Locating a structural BMP within an area that is expressly prohibited by law.
- Locating a structural BMP within an area that is strongly discouraged, and is only allowed on a case-by-case basis. Local, state and/or federal permits may be needed, and the applicant will need to supply additional documentation to justify locating the BMP within the regulated area.
- Locating a BMP based upon setbacks from a site feature or features.

This checklist is only intended as a general guide to location and permitting requirements as they relate to siting of stormwater structural BMPs. Knox County advises that the appropriate permitting agency be consulted if any of the site features listed in Table 4-6 are encountered on the development or redevelopment site.

4.2.5 Limited Application BMP Screening Process

Outlined below is a screening process for limited application BMPs designed to assist the site designer and design engineer in the evaluation of the performance and applicability of the various limited application BMPs. Through the use of Table 4-7, the site designer can evaluate and screen the list of limited application structural BMPs to determine if a particular BMP or set of BMP(s) is appropriate.

As with the general application BMPs, the site designer assesses the physical and environmental features at the site to determine the optimal location for the selected BMP(s) or group of BMPs using Table 4-7 (Location and Permitting Checklist).

Evaluation Criteria

The following are the details of the various screening categories and individual characteristics used to evaluate the structural BMPs listed in Table 4-7.

Water Quality Treatment

% TSS Reduction. This column indicates the pollutant removal value assigned to each BMP type. If the BMP has a value of less than 80% TSS, then the BMP must be used in a treatment train with other BMPs to meet the overall weighted TSS reduction goal.

Table 4-6. BMP Location and Permitting Checklist

Site Feature and Regulatory Agency	General Location and Permitting Guidance
Jurisdictional Wetlands (Waters of the U.S) U.S. Army Corps of Engineers Section 404 Permit Knox County Engineering	• Jurisdictional wetlands should be delineated prior to siting structural control. • Use of natural wetlands for stormwater quality treatment is contrary to the goals of the Clean Water Act and should be avoided. • Stormwater should be treated prior to discharge into a natural wetland. • Structural BMPs may also be restricted in buffer zones, although they may be utilized as a non-structural filter strip (i.e., accept sheet flow). • Justification must be provided that no practical upland treatment alternatives exist for wetland impacts by structural BMPs. • Where practical, excess stormwater flows should be conveyed away from jurisdictional wetlands or as sheet flow towards the wetland.
Stream Channels (Waters of the U.S) U.S. Army Corps of Engineers Section 404 Permit TDEC Knox County Engineering	• All Waters of the U.S. (streams, ponds, lakes, etc.) should be delineated prior to design. • Waters of the U.S. should not be used for stormwater quality treatment. In-stream ponds for stormwater quality treatment are highly discouraged. • Stormwater should be treated prior to discharging into Waters of the U.S. • Justification must be provided that no practical upland treatment alternatives exist for stream impacts by structural BMPs. • Temporary runoff storage preferred over permanent pools. • Implement measures that reduce downstream warming.
Sinkholes TDEC Knox County Engineering	• The Director may require additional BMPs to prevent flooding or additional information to verify structural integrity.
Wellhead Protection Zones TDEC	• Infiltration BMPs may be prohibited due to proximity to wellhead protection zones for public water supplies. TDEC required setbacks for public water systems categories 1-4 will be enforced.
100 Year Floodplains Knox County Engineering	• Grading and fill for structural control construction is generally discouraged within the ultimate 100 year floodplain, as delineated by FEMA flood insurance rate maps, FEMA flood boundary and floodway maps, or as determined by the Director. • Fill that alters the conveyance and storage capacity of the natural floodplain is prohibited in the flood fringe one-half the linear distance between the floodway line and the 100-year floodplain line.
Water Quality Buffers Knox County Engineering	• Structural BMPs are prohibited in the inner zone of buffers on streams and wetland buffers.
Utilities Local utility district	• Call appropriate utility district to locate existing utilities prior to design. • Note the location of proposed utilities to serve development. • Structural BMPs are discouraged within utility easements or rights-of-way for public or private utilities.
Roads Knox County Engineering TDOT	• Approval must also be obtained for any stormwater discharges to a Knox County or state-owned conveyance channel.
Structures and Property Lines Knox County	• Consult the Volume 2, Chapter 4 of the Knox County Stormwater Management Manual for structural BMP setbacks from structures. • Recommended setbacks for each structural BMP group are provided in the performance criteria in this manual.
Septic Drainfields Knox County Health Department	• Consult Knox County Health Department. • Recommended setback is a minimum of 50 feet from drain field edge.

Site Feature and Regulatory Agency	General Location and Permitting Guidance
Water Wells Knox County Health Department	• 100-foot setback for stormwater infiltration. • 50-foot setback for all other structural controls.

Site Applicability

The next two columns in Table 4-7 provide an overview of the specific site conditions or criteria that must be met for a particular limited application structural BMP to be suitable. Please see the specific criteria for each BMP provided in Section 4.3 for more details.

Drainage Area. This column indicates the approximate minimum or maximum drainage area that is considered suitable for the structural BMP.

Space Required (Space Consumed). This comparative index expresses how much space a structural BMP typically consumes at a site in terms of the approximate area required as a percentage of the impervious area draining to the control.

Implementation Considerations

The last group of columns in Table 4-7 provides additional considerations for the applicability of each structural BMP option.

Residential Subdivision. A check mark in this column identifies whether or not a structural control is suitable for typical residential subdivision development (not including high-density or ultra-urban areas).

High Density / Ultra-Urban. A check mark in this column identifies those structural controls that are appropriate for use in very high-density (ultra-urban) areas, or areas where space is a premium.

Capital Cost. The structural controls are ranked according to their relative construction cost per impervious acre treated as determined from cost surveys.

Maintenance Burden. This column assesses the relative maintenance effort needed for a structural stormwater control, 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 structural BMPs require routine inspection and maintenance.

Commercially Manufactured Systems Available? This column indicates if a structural control is available as a pre-manufactured commercial product from a vendor.

4.2.6 Off-Line Versus On-Line Structural BMPs

Structural stormwater controls are designed either as “off-line” or “on-line” stormwater quality treatment controls. Examples of off-line and on-line BMPs are presented in Figure 4-1.

Off-line structural BMPs provide stormwater treatment (or other control) away from the flowpath of the runoff, and therefore, are typically designed only to receive a specified discharge rate (the water quality peak discharge) or volume. After the design runoff flow has been treated and/or controlled it is returned to the conveyance system. In contrast, on-line facilities, such as a stormwater treatment channel, typically provide stormwater control within the flowpath of the runoff. Because of this, on-line facilities often must be able to handle the entire range of design storm discharges, up to the Qp_{25} or Qp_{100} event. Techniques and calculation methods for proper sizing of off-line BMPs are presented in Volume 2, Chapter 3 of this manual

A flow regulator (e.g., diversion structure, flow splitter, etc.) is used to direct stormwater to off-line structural BMPs. Examples of flow regulators are shown in Figures 4-2 through 4-4 below.

Table 4-7. Limited Application BMP Screening Matrix

STRUCTURAL BMP CATEGORY	STRUCTURAL BMP	WATER QUALITY	SITE APPLICABILITY		IMPLEMENTATION CONSIDERATIONS				
		% TSS Reduction	Drainage Area (acres)	Space Req'd (% of tributary imp. Area)	Residential Subdivision Use	High Density / Ultra-Urban	Capital Cost	Maintenance Burden	Commercially Manufactured Systems Available?
Filtering Practices	Organic Filter	80	10 max**	2-3%		✓	High	High	
	Underground Sand Filter	80	5 max	None		✓	High	High	Yes
Wetland Systems	Submerged Gravel Wetland	80	5 max**	2-3%		✓	High	High	
Porous Surfaces[1]	Porous Concrete	*	5 max	Varies		✓	Medium	High	
	Modular Porous Paver Systems	*	5 max	Varies	✓	✓	High	High	Yes
Chemical Treatment	Alum Treatment System	90	25 min	None	✓	✓	High	High	
Proprietary Systems	Commercial Stormwater Controls*	***	***	***	***	***	***	***	Yes
Separator Units	Oil/Grit Oil/Water Gravity	30	1 max	***		✓	Medium	High	Yes

✓ Meets suitability criteria
* These practices are source controls and are not designed as pollutant removal devices.
** Drainage area can be larger in some instances
*** The application, performance and maintenance requirements of specific commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data
[1] Porous surfaces provide water quantity benefits by reducing the effective impervious area

Figure 4-1. Example of Off-Line versus On-Line Structural Controls

(Source: Center for Watershed Protection, 1996)

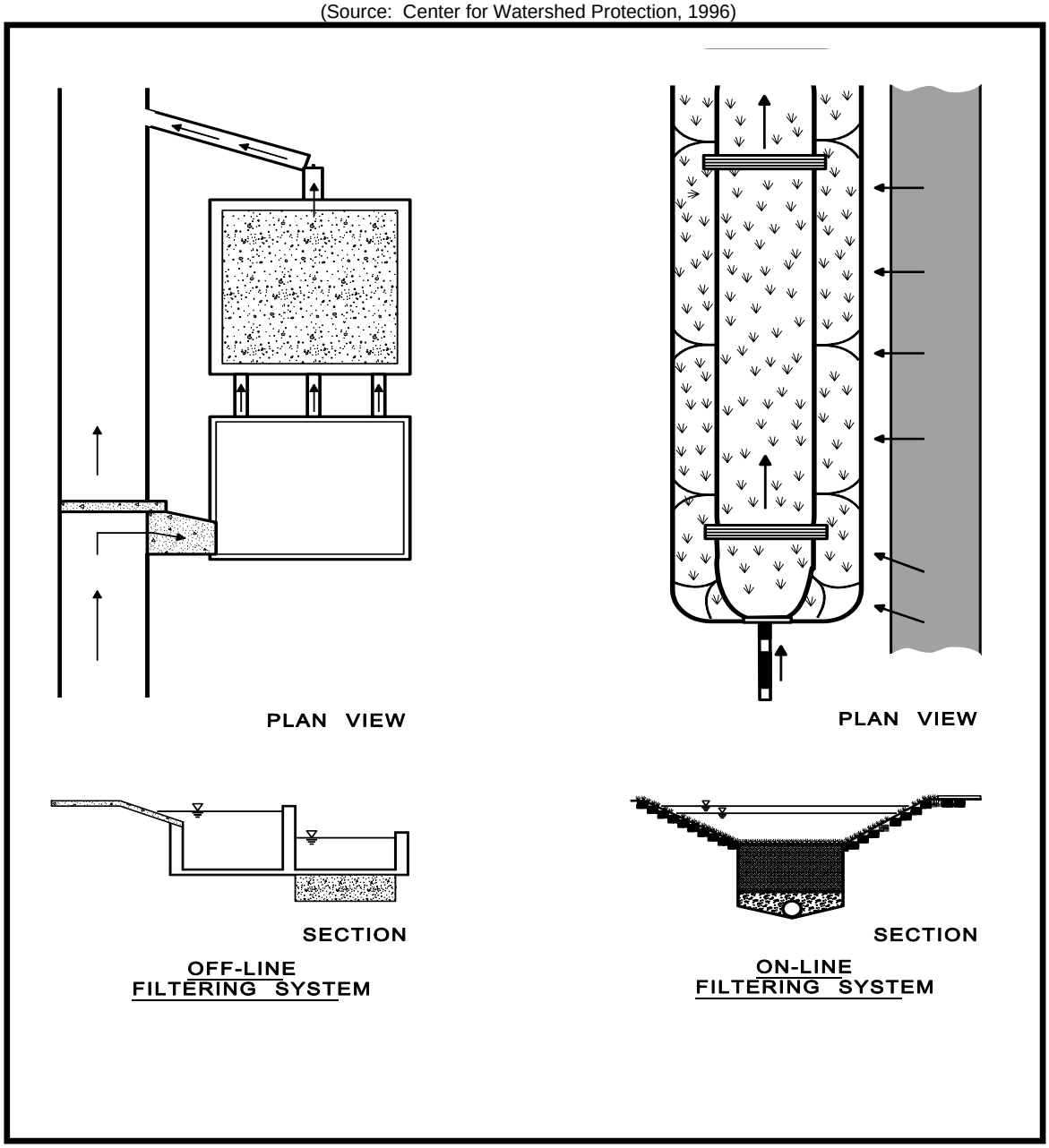


Figure 4-2. Pipe Interceptor Diversion Structure
(Source: City of Sacramento, 2000)

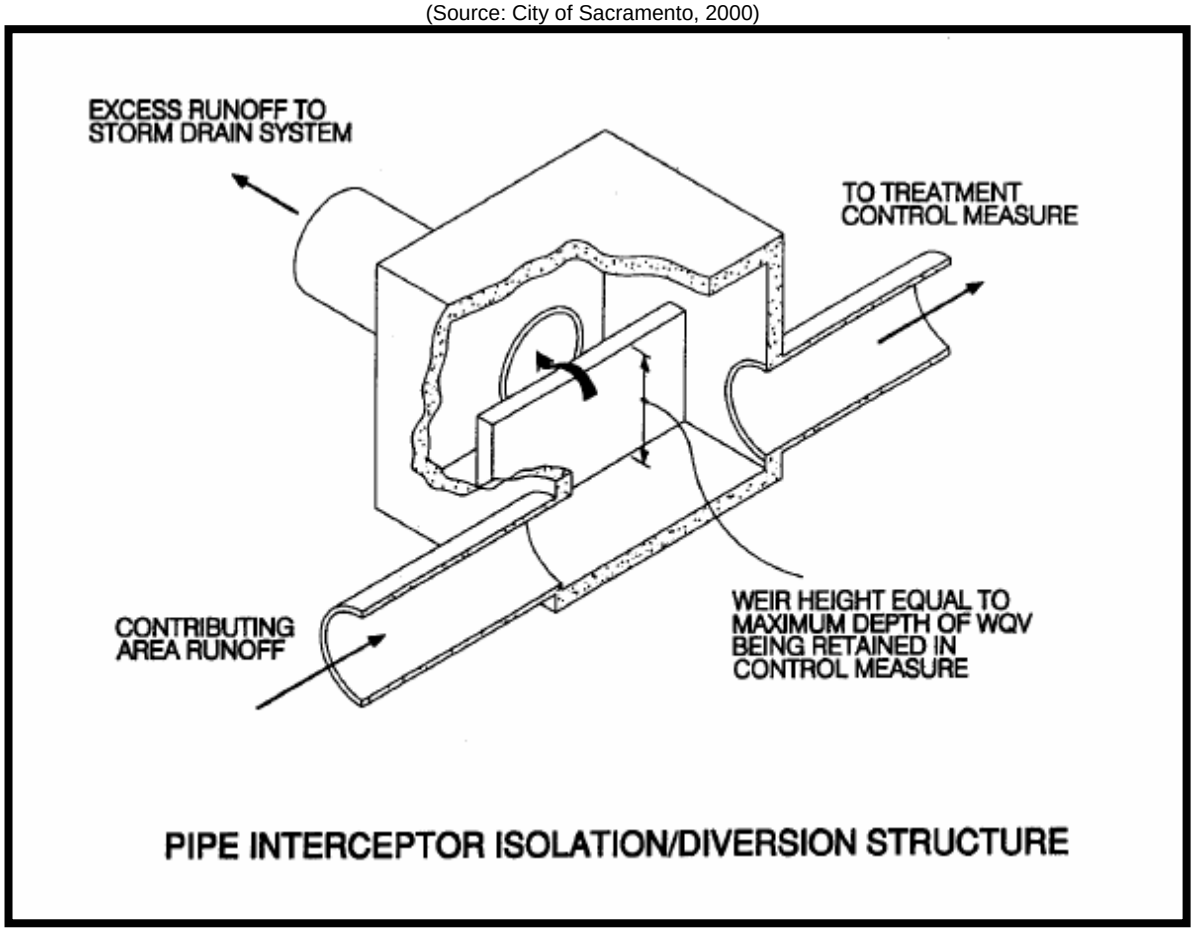


Figure 4-3. Regulator
(Source: City of Sacramento, 2000)

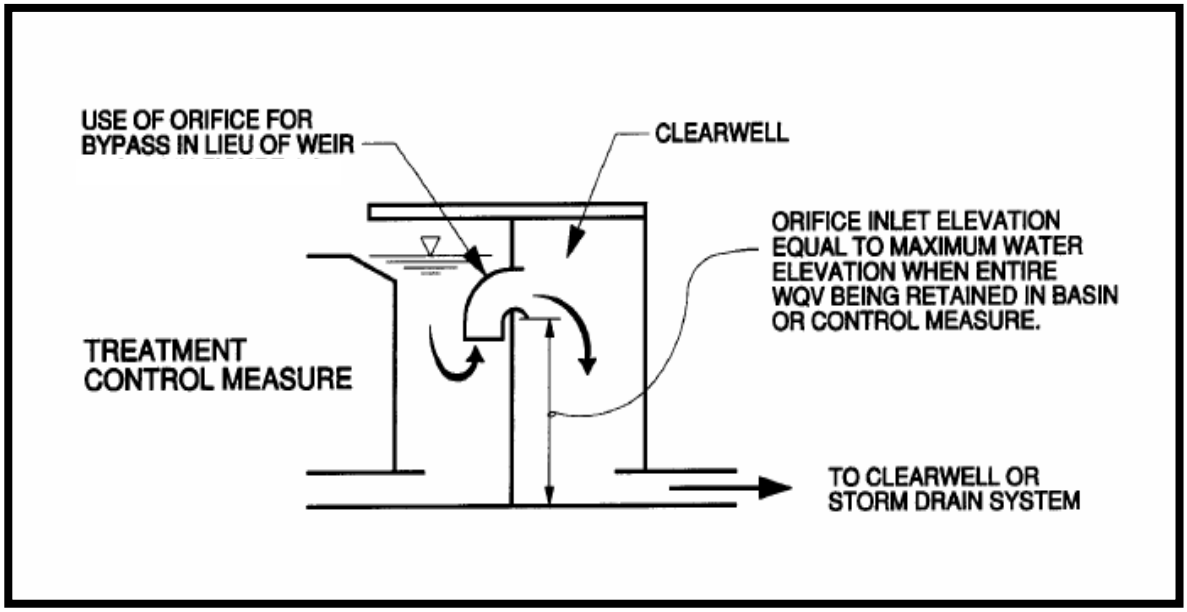
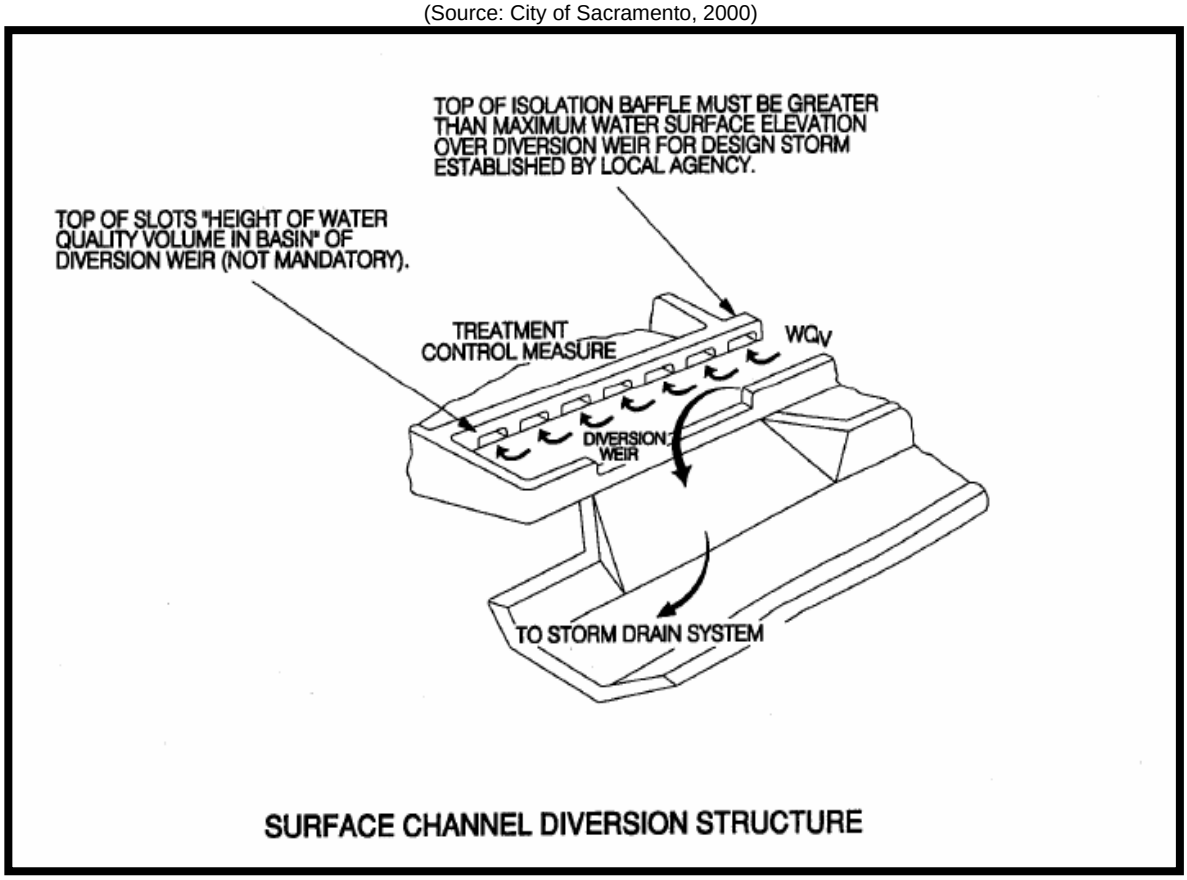


Figure 4-4. Surface Channel Diversion Structure
(Source: City of Sacramento, 2000)



4.2.7 Using Structural Stormwater BMPs in Series

The minimum stormwater management standards are an integrated planning and design approach whose components work together to limit the adverse impacts of urban development on downstream waters and riparian areas. This approach is sometimes called a stormwater "treatment train", where two or more structural (and sometimes non-structural) BMPs work in series to treat and control stormwater runoff. The calculation of % TSS removal for BMPs in series is discussed in detail in Volume 2, Chapter 2.

When considered comprehensively, a treatment train consists of all the design concepts and nonstructural and structural BMPs that work to attain water quality and quantity goals. This is illustrated in Figure 4-5, and is described below.

Figure 4-5. Generalized Stormwater Treatment Train

Runoff and Load Generation – The initial part of the "train" is located at the source of runoff and pollutant load generation, and consists of better site design and pollution prevention practices that reduce runoff and stormwater pollutants.

Pretreatment – The next step in the treatment train consists of pretreatment measures. These measures typically do not provide sufficient pollutant removal to meet the 80% TSS reduction goal, but do provide calculable water quality benefits that may be applied towards meeting the WQv treatment requirement. These measures include:

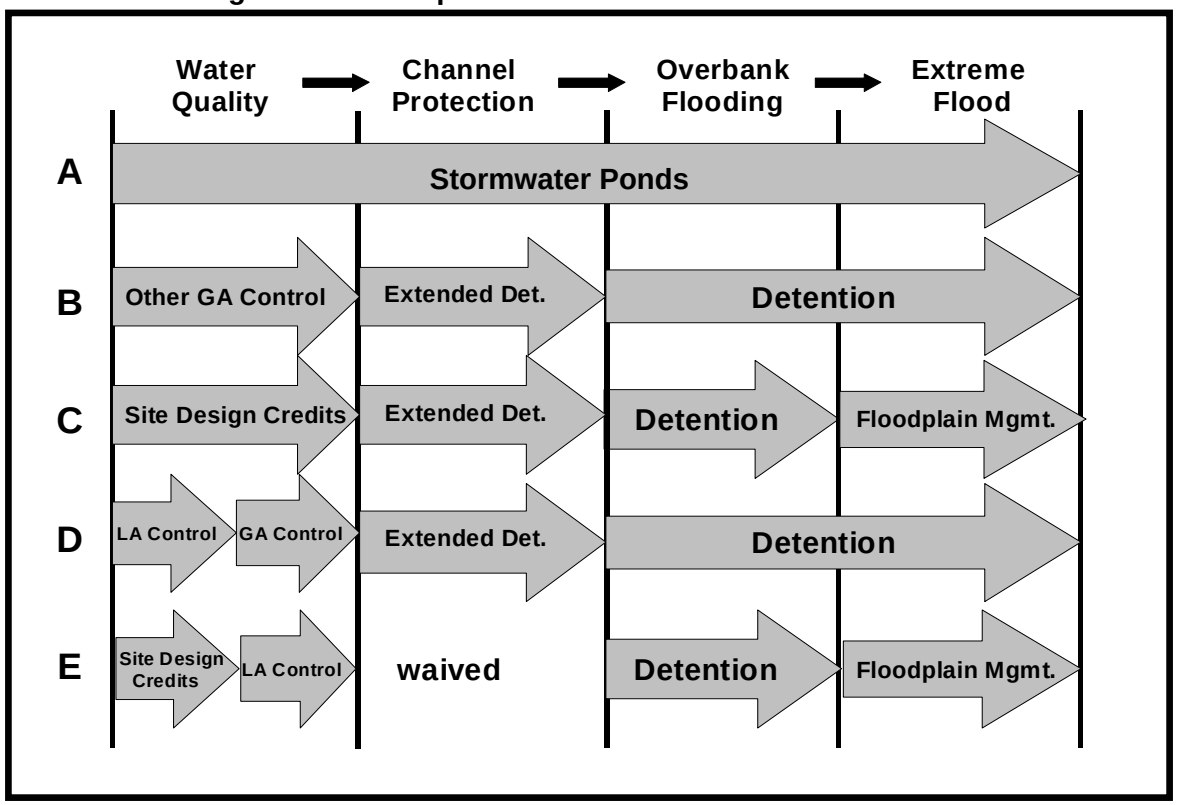
- The use of stormwater better site design practices and site design credits to reduce the generation of stormwater runoff and thereby reducing the WQv
- Limited application BMPs that provide pretreatment
- Pretreatment facilities such as sediment forebays on General Application BMPs

Primary Treatment and/or Quantity Control – The last step is primary water quality treatment and/or quantity (channel protection, overbank flood protection, and/or extreme flood protection) control. This is achieved through the use of general or limited application BMPs, or detention facilities. It should be noted that controls installed to reduce the runoff load and to provide pretreatment can affect the size of the primary treatment control.

4.2.7.1 Use of Multiple Structural BMPs in Series

Many combinations of structural BMPs in series may exist for a site. Figure 4-6 provides a number of hypothetical examples of structural BMPs, that when used in a treatment train, can satisfy Knox County's stormwater design criteria for water quality treatment, channel protection, overbank flooding and extreme flooding. In Figure 4-6, GA indicates General Application BMPs, LA indicates Limited Application BMPs.

Figure 4-6. Examples of Structural BMPs Used in Series



Referring to Figure 4-6 by line letter:

A. One general application BMP, stormwater ponds, can be used as a stand-alone to meet all the design criteria.

B. Other general application (GA) BMPs (bioretention, sand filters, infiltration trench and enhanced swale) are typically used in combination with detention controls to meet the WQv, CPv, Qp_{25} and Qp_{100} criteria. The detention facilities are located downstream from the water quality controls either on-site or combined into a regional or neighborhood facility.

C. Line C indicates the condition where an environmentally sensitive large lot neighborhood (discussed in Volume 2, Chapter 5) has been developed that can be designed so as to waive the water quality treatment requirement altogether. However, detention controls may still be required for downstream channel protection, overbank flood protection and extreme flood protection.

D. Where a limited application (LA) structural BMP does not meet the 80% TSS removal criteria, another downstream structural control must be added. For example, an urban hotspot land use may be fit or retrofit with devices adjacent to parking or service areas designed to remove oil and grease and may also serve as pretreatment devices removing the coarser fraction of sediment. One or more downstream structural controls is then used to meet the full 80% TSS removal goal, and well as water quantity control.

E. In Line E site design credits have been employed to partially reduce the water quality volume requirement. In this case, for a smaller site, a well designed and tested Limited Application structural control provides adequate TSS removal while a dry detention pond handles the overbank flooding criteria. For this location, direct discharge to a large stream and local downstream floodplain management practices have eliminated the need for channel protection volume and extreme flood protection structural controls on site.

The combinations of structural stormwater BMPs are limited only by the need to employ measures of proven effectiveness and meet local regulatory and physical site requirements. Figures 4-7, 4-8 and 4-9, illustrate the application of the treatment train concept for: a moderate density residential neighborhood, a small commercial site, and a large shopping mall site, respectively.

In Figure 4-7 rooftop runoff drains over grassed yards to backyard grass channels. Runoff from front yards and driveways reaches roadside grass channels. Finally, all stormwater flows to a micropool ED stormwater pond.

A gas station and convenience store is depicted in Figure 4-8. In this case, the decision was made to intercept hydrocarbons and oils using a commercial gravity (oil-grit) separator located on the site prior to draining to a perimeter sand filter for removal of finer particles and TSS. Overbank and extreme flood protection is provided by a regional stormwater control downstream.

Figure 4-9 shows an example treatment train for a commercial shopping center. In this case, runoff from rooftops and parking lots drains to a depressed parking lot, perimeter grass channels, and bioretention areas. Slotted curbs are used at the entrances to these swales to better distribute the flow and to settle out the very coarse particles at the parking lot edge for sweepers to remove. Runoff is then conveyed to a wet ED pond for additional pollutant removal and channel protection. Overbank and extreme flood protection is provided through parking lot detention.

Figure 4-7. Example Treatment Train – Residential Subdivision
(Adapted from: Atlanta Regional Council, 2001)

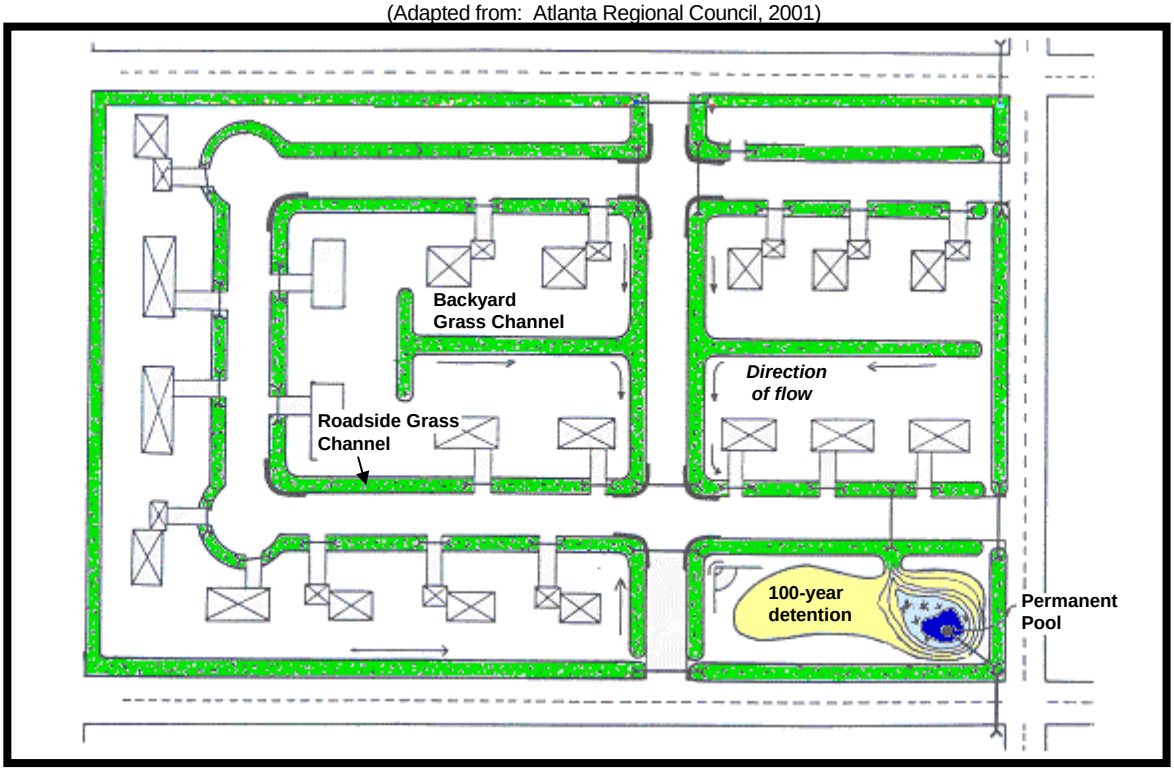


Figure 4-8. Example Treatment Train – Commercial Development

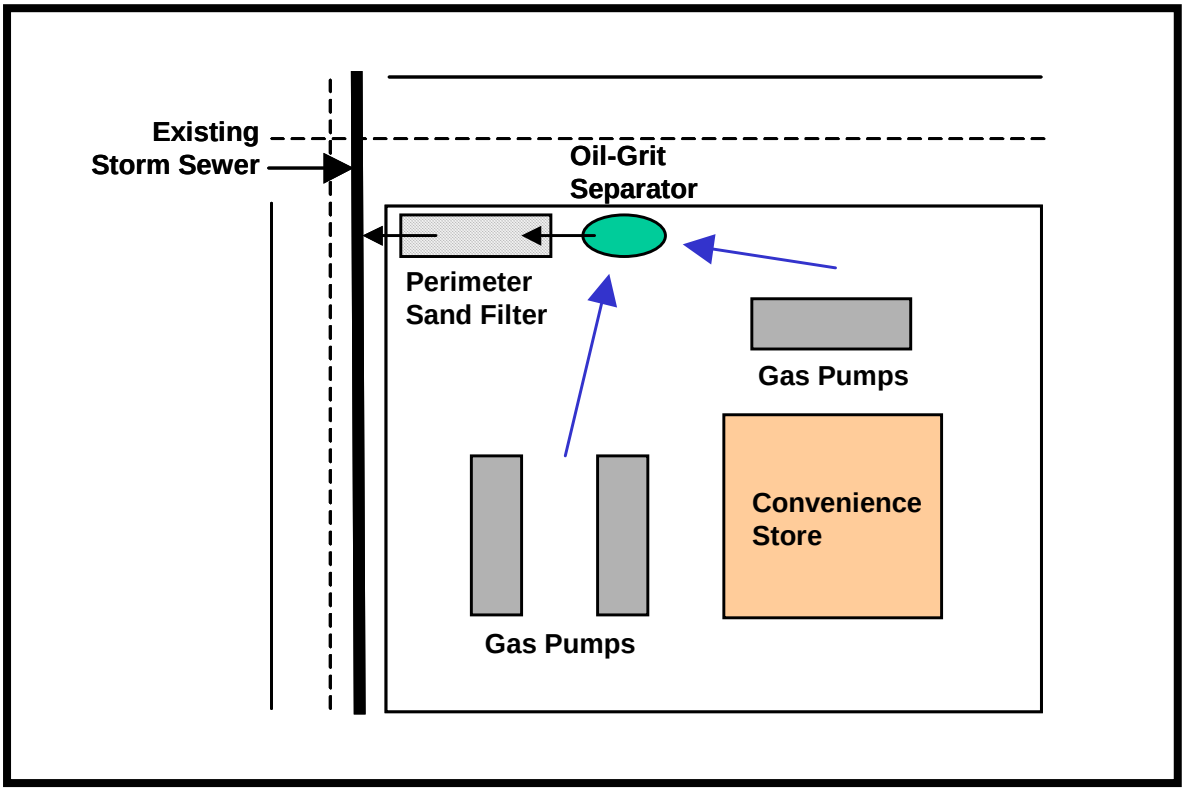
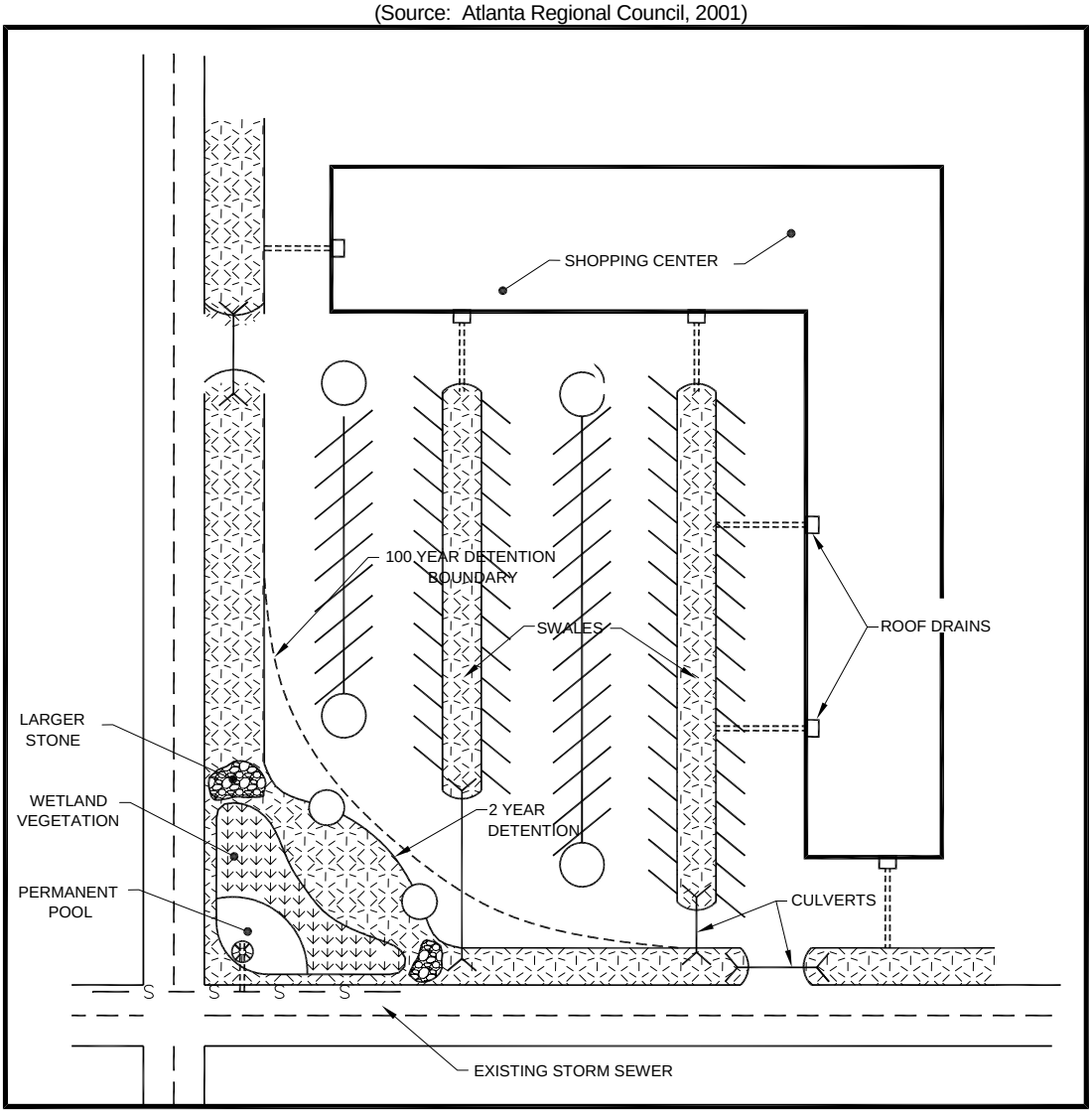


Figure 4-9. Example Treatment Train – Commercial Development

(Source: Atlanta Regional Council, 2001)



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