2.2 Stormwater Quality Management

2.2.1 General Requirements and Policies

The Knox County Stormwater Management Ordinance requires that stormwater runoff discharging from new development or redevelopment sites be treated to remove pollutants prior to discharge from the site. Minimum Standard #1 (Chapter 1) states that stormwater management systems shall be designed to remove 80% of the average annual post-development total suspended solids (TSS) load and be able to meet any other additional watershed or site-specific water quality requirements. This standard is often referred to as "the 80% TSS removal standard".

The Director has the authority to require additional treatment in specific areas of Knox County, to conform to state and/or Federal regulatory requirements, and/or if (in the opinion of the Director) the development or redevelopment has the potential to generate higher than normal pollutant discharges.

It is presumed that a stormwater management system complies with the 80% TSS removal standard if appropriate structural best management practices (BMPs) are selected, designed, constructed and maintained in accordance with the design criteria specified in this manual. Only those BMPs that are published in the Knox County Stormwater Management Manual are permitted for use as a water quality treatment practice in Knox County. Other BMPs are prohibited, unless approved by the Director.

2.2.2 Percent TSS Removal Values for Structural BMPs

The structural stormwater BMPs deemed acceptable for use in Knox County to attain the 80% TSS removal standard are listed in Table 2-2, which presents the % TSS removal value assigned to each BMP. This value must be used to calculate the total weighted % TSS removal for the development site. The % TSS removal values assigned to each BMP are conservative median pollutant reduction percentages for design purposes that have been derived from existing sampling data, modeling and professional judgment. A structural BMP design may be capable of exceeding these performances; however, the values in the table are median values that can be achieved over time when the structural BMP is sized, designed, constructed and maintained in accordance with required specifications in this manual. The actual % TSS removal value for a BMP in any single storm event may be higher or lower, depending upon a number of factors, including the inflow pollutant concentration, type of storm event, and maintenance condition of the BMP.

The structural BMPs listed in Table 2-2 fall into two categories (general application or limited application) based upon the BMP's ability to meet stormwater management goals and/or its maintenance requirements. Further discussion of these categories and detailed guidance on BMP selection, design, construction, and maintenance are presented in Volume 2, Chapter 4 for each BMP listed in Table 2-2.

2.2.2.1 Policies for New or Proprietary BMPs

There are many commercially available BMPs that provide water quality or quantity treatment (e.g., Stormceptor, Vortechnics, etc.). Typically, such "proprietary" controls have high installation and maintenance costs and requirements; and therefore, they are best suited for non-residential developments or redevelopments that have limited space for water quality or quantity treatment using standard BMPs. This section describes the requirements that must be met for proprietary BMPs to be approved for a given site.

Table 2-2. TSS Removal % for Structural BMPs

Structural BMP	TSS Removal %
General Application BMPs	

Wet Pond	80
Wet Extended Detention	80
Micropool Extended Detention Pond	80
Multiple Pond System	80
Dry Extended Detention Pond	60
Conventional Dry Detention Basins	10
Shallow Wetland	75
Extended Detention Shallow Wetland	75
Pond/Wetland System	75
Pocket Wetland	75
Bioretention Area	85
Sand Filters (Surface and Perimeter)	80
Infiltration Trench	90
WQ Dry Swales	90
Wet Swales	75
Filter Strip	50
Grass Channel[1]	30
Gravity (oil-grit) Separator	30
Modular Porous Paver Systems[2]	*
Porous Pavement/Concrete[2]	*
Limited Application BMPs	
Organic Filter	80
Underground Sand Filter	80
Submerged Gravel Wetland	75
Alum Treatment System	90
Proprietary Treatment Controls	10[3]
Underground Detention	10

1 – Refers to open channel practice not designed for water quality.
2 – These practices are not treatment BMPs but are source control BMPs, so they are not assigned a pollutant removal.
3 – Provisional % TSS Removal value pending third party information.

Proprietary BMPs, new BMPs, or technologies that are not included in this manual may be approved by the Director on a case-by-case basis for the treatment of stormwater quality. A TSS removal percentage of 10% shall be used for such BMPs (if approved), or a higher percentage may be approved provided that the three conditions listed below are met. Judgments of the above three conditions shall be made by the Director after review of applicable information submitted by the site designer. A poor performance record, high failure rate or unacceptably high maintenance requirements are all valid justifications for not allowing the use of a proprietary system or device. It is the responsibility of the developer to provide the Director with sufficient information to allow modification of the % TSS removal value for any proprietary BMPs.

1. The BMP or technology, as applied to the development or redevelopment on which it will be used, meets the minimum standards and design criteria published in the Knox County Stormwater Management Manual. The performance ability of the BMP must be verified by an independent third party, in accordance with the monitoring criteria presented below. If the performance ability of the BMP cannot be verified, the BMP will not be approved for purposes of stormwater quality treatment.
2. The BMP or technology must have a proven record of operational longevity under hydrologic conditions similar to what would be encountered in Knox County (rainfall, slope, soil types, etc.).
3. The BMP or technology must have documented procedures for inspection and maintenance, including the collection and removal of pollutants or debris. BMPs that have unacceptably high maintenance requirements may not be installed within public rights-of way or on public property.

The following monitoring criteria should be met for research/studies to support the three acceptance conditions stated above:

- Water quality treatment performance must be monitored for a minimum of fifteen (15) storm events.
- Water quality treatment performance research/monitoring must be conducted in the field, as opposed to laboratory testing.
- Field monitoring must be conducted using standard protocols which require proportional sampling both upstream and downstream of the device. For guidance on testing protocols, see "Stormwater Best Management Practices Demonstration Tier II Protocol for Interstate Reciprocity" as developed under the Environmental Council of States (ECOS) and Technology Acceptance and Reciprocity Partnership (TARP, 2001).
- Pollutant concentrations reported in the study must be flow-weighted.
- The proprietary system or device must have been utilized in place for at least one year prior to the time of monitoring.
- Although local data is preferred, data from other areas can be accepted as long as the design accounts for the local hydrologic conditions.

2.2.3 Calculation of WQv and % TSS Removal

Compliance with the % TSS removal standard requires the calculation of the WQv and % TSS removed for the entire development site. To obtain the lowest WQv for the site, this calculation should be performed *after* better site design practices that may be envisioned for the site have been considered and are included in design plans.

The WQv shall be calculated using Equation 2-1, as follows:

Equation 2-1

$$WQv = \frac{P \times Rv \times A}{12}$$

where:

WQv = water quality volume of the site (acre-feet);
P = rainfall depth for the 85% storm event (1.1 inches);
Rv = runoff coefficient; and,
A = site area (acres).

The runoff coefficient (Rv) shall be calculated using Equation 2-2.

Equation 2-2 $$Rv = 0.015 + 0.0092 \times I$$

where:

HRI = percent impervious area of the site (see Equation 2-5 below).

The percent TSS removal (%TSS) that is achieved on a site can be calculated using Equation 2-3. Equation 2-3 is an area-weighted TSS reduction equation which accounts for the TSS reduction that is contributed from each stormwater treatment BMP that is utilized on the site.

Equation 2-3 $$\%TSS = \frac{\sum_n^1 (TSS_1 A_1 + TSS_2 A_2 + ... + TSS_n A_n)}{\sum_n^1 (A_1 + A_2 + ... + A_n)}$$

where:

TSS_n = TSS removal percentage for each structural BMP located on-site (%);
A_n = the area draining to each BMP (acres).

Where BMPs are used in series, the total % TSS removal for the combination of two or more BMPs shall be used for TSS_n in Equation 2-3. Calculation of this value is discussed in the next section.

2.2.4 Calculation of % TSS Removal for BMPs in Series

It will often be the case that the site designer will want to use two or more BMPs (structural and/or non-structural) in series, where stormwater treated in one BMP is discharged into another BMP for further treatment. Such BMP combinations are also called treatment trains. How and why BMPs might be used in treatment trains is discussed in Volume 2, Chapter 4 of this manual. This section presents the calculation of the total % TSS removal for treatment trains.

Pollutant removal rates for BMPs used in a treatment train are not additive. For pollutants in particulate form, such as TSS, the actual removal rate (expressed in terms of percentage of pollution removed) varies directly with the pollution concentration and sediment size distribution of runoff entering a facility. For example, a stormwater treatment pond will have a much higher pollutant removal percentage for very turbid runoff than for relatively clear water. When two stormwater ponds are placed in series, the downstream pond will treat an incoming TSS load that is very different from the upstream pond. The upstream pond easily captures the larger solids, and discharges an outflow that has a lower concentration of TSS, but with a relatively higher proportion of fine particle sizes. Hence, the TSS removal capability of the downstream pond is considerably less than the upstream pond. Recent studies suggest that the downstream pond in a series can provide as little as half the removal efficiency of the upstream pond.

To calculate the total % TSS removal for a treatment train comprised of two or more structural BMPs, Equation 2-4 shall be used.

Equation 2-4 $$TSS_{train} = A + B - \frac{(A \times B)}{100}$$

where:

TSS_{train} = total TSS removal for treatment train (%);
A = % TSS removal of the first (upstream) BMP, from Table 2-2 (%)
B = % TSS removal of the second (downstream) BMP, from Table 2-2 (%).

For development sites where the treatment train provides the only stormwater treatment on the site, TSS_{train} must be greater than or equal to 80%. For development sites that have other structural BMPs for stormwater treatment that are not included in the treatment train, TSS_{train} must be included in Equation 2-3 in the calculation of the overall % TSS removal for the site. An example application of the latter situation is presented below.

Example 2-1. Calculation of %TSS when Treatment Trains are Used

A stormwater management system located on a 30 acre development site consists of a dry extended detention pond, a water quality dry swale, and a shallow wetland. The extended detention pond and dry swale are located in series, with the pond as the upstream control. The treatment train treats stormwater runoff from 20 acres of the site. The shallow wetland treats 10 acres. All three facilities are designed in accordance with the Knox County Stormwater Management Manual. What is the % TSS removal rate for the site?

The % TSS removal value for each BMP located on the site is determined from Table 2-2, as follows:

Control A (dry extended detention pond) = 60% TSS removal
Control B (water quality dry swale) = 90% TSS removal
Control C (shallow wetland) = 75% TSS removal

Step 1: Calculate TSS_{train}:
TSS_{train} = A + B – (A x B)/100 = 60 + 90 - (60 X 90)/100 = 96% removal

Step 2: Calculate % TSS removal for the site:
%TSS = ((TSS_{train} x 20 acres) + (%$TSS_{wetland}$ x 10 acres)) ÷ 30 acres
%TSS = ((96% x 20 acres) + (75% x 10 acres)) ÷ 30 acres = 89%

Therefore, the % TSS removal for the site is 89%, which exceeds the minimum standard of 80% TSS removal. No other BMPs need to be constructed at the site.

2.2.5 The Measurement and Calculation of Percent Imperviousness

The percent impervious area (I) that is used to determine WQv is calculated using Equation 2-5.

Equation 2-5

$$I = \frac{I_A}{A} \times 100\%$$

where:

I_A = cumulative area of all impervious surfaces on the site (acres);
A = site area (acres).

Impervious areas are defined in the Knox County Stormwater Management Ordinance as impermeable surfaces which prevent the percolation of water into the soil including, but not limited to, paved surfaces such as walkways, sidewalks, patios, parking areas and driveways, packed gravel or soil, and rooftops. Other examples of impervious areas are paved recreation areas including pool houses and pool decks intended for use as a private (multi-family) or public recreation area, paved athletic courts (e.g., basketball, tennis), and storage buildings.

The determination of the impervious area (I_A) in order to calculate WQv shall be performed in the following manner:

1. For residential subdivisions that will be served by one or more shared stormwater facilities, I_A shall be determined using percent (%) impervious values that were developed by the Soil Conservation Service

(SCS)[1]. Where the average lot size of a subdivision or a drainage area within the subdivision falls between the lot size categories shown in Table 2-3, the site designer may interpolate the % impervious value based on Table 2-3.

The values shown in Table 2-3 shall be utilized only for the portion of the subdivision that is covered by individual residential lots and streets. Other areas, such as common areas for recreation or meeting facilities, shall be added separately in the calculation of I_A. The calculation of the % impervious value for a residential subdivision having a common area is presented in Example 2-2.

If lot sizes within a single subdivision fall into more than one of the lot size ranges listed in Table 2-3, the site designer shall consider the total amount of imperviousness in each lot range separately in the determination of the percent impervious value. Example 2-2 includes the calculation of the % impervious value for a residential subdivision having variable lot sizes.

Table 2-3. % Impervious Area Values for Subdivisions

Residential Lot Size Range[1]	% Impervious
⅛ acre or less	65
¼ acre	38
⅓ acre	30
½ acre	25
¾ acre	22.5[2]
1 acre	20
2 acres and greater	15

1 – Includes lots and streets. Common areas must be measured separately.
2 – The % impervious value is interpolated from SCS data.

2. For all other developments and redevelopments, I_A shall be determined from the measured impervious footprints for all impervious areas as defined above. It is required that the footprint for all impervious surfaces in the proposed development and the calculation of I_A be shown in the stormwater management plan.

After the development and/or redevelopment of the property is complete, property improvement activities that do not require the submittal of a stormwater management plan will not require recalculation of the impervious percentage and WQv.

Example 2-2. Calculation of Percent Impervious Area (I)

A site design engineer is preparing a stormwater management plan for a proposed residential development in Knox County. The subdivision has a total area of 31 acres, and will include 52 residential lots ranging in area from approximately ¼ acre to no greater than 1 acre (as shown in the table below). Three (3) acres will be preserved as an undisturbed forested water quality buffer located along a stream that crosses the property, and therefore, there is no impervious coverage within these three acres. Another three (3) acres will be utilized for a recreational common area which includes a community pool, tennis courts and an associated parking lot. Due to local topography on the site, the subdivision drains to two separate stormwater facilities, herein called Facility A and Facility B, both of which provide stormwater quality treatment. Twelve acres, including the 3 acre water quality buffer and 3 acre common area, drain to Facility A. The other 19 acres drains to Facility B. The table below provides lot size, area and impervious data for the proposed subdivision. What is the % impervious area for the site?

[1] The Soil Conservation Service is now known as the Natural Resource Conservation Service.

A Lot Size	B Number of Lots in Size Range	C Sub-total Area of Lots in Size Range	D % Impervious (from Table 2-3)
DRAINAGE AREA A (AREA DRAINING TO FACILITY A)			
approx. ⅓ acre	0	0 acres	30
approx. ½ acre	0	0 acres	25
approx. ¾ acre	2	1.3 acres	22.5
approx. 1 acre	5	4.7 acres	20
Area A Totals	7 lots	6.0 acres	--
DRAINAGE AREA B (AREA DRAINING TO FACILITY B)			
approx. ⅓ acre	21	6.6 acres	30
approx. ½ acre	16	7.3 acres	25
approx. ¾ acre	7	4.3 acres	22.5
approx. 1 acre	1	0.8 acres	20
Area B Totals	45 lots	19.0 acres	--

Since the site will be served by two separate detention facilities, it is best to determine the impervious area for each drainage area, rather than the overall impervious area for the site.

<u>Step 1:</u> Determine the total impervious area for the portion of each drainage area that is covered by residential lots and associated subdivision roads ($I_{\text{residential areas}}$):

This is calculated by multiplying the sub-total area of each lot size range (column C from the above table) by the corresponding % impervious in that lot size range (column D from the above table). Results of this calculation are shown in the table below.

A Lot Size	B Sub-total Area of Lots in Size Range	C % Impervious (from Table 2-3)	D Sub-total Impervious Area
DRAINAGE AREA A (AREA DRAINING TO FACILITY A)			
approx. ⅓ acre	0 acres	30	0 x 0.30 = 0 ac
approx. ½ acre	0 acres	25	0 x 0.25 = 0 ac
approx. ¾ acre	1.3 acres	22.5	1.3 x 0.225 = 0.29 ac
approx. 1 acre	4.7 acres	20	4.7 x 0.20 = 0.94 ac
Area A Totals	6.0 acres	--	1.23 acres
DRAINAGE AREA B (AREA DRAINING TO FACILITY B)			
approx. ⅓ acre	6.6 acres	30	6.6 x 0.30 = 1.93 ac
approx. ½ acre	7.3 acres	25	7.5 x 0.25 = 1.88 ac
approx. ¾ acre	4.3 acres	22.5	4.3 x 0.225 = 0.97 ac
approx. 1 acre	0.8 acres	20	0.8 x 0.20 = 0.16 ac
Area B Totals	19.0 acres	--	4.94 acres

Thus, the portions of the site where residential lots are located are covered by impervious surfaces as follows:
$I_{A\ residential\ areas}$ = 1.23 acres
$I_{B\ residential\ areas}$ = 4.94 acres

Step 2: Measure the area of impervious footprints in the common areas that are located in Area A ($I_{A\ common\ areas}$):

The following table presents the measurements of the impervious areas located in the common area.

Area Description	Impervious Area
Community pool (includes pool, surrounding deck, maintenance building and sidewalk from parking lot)	0.8 acres
Tennis court (includes two courts, surrounding paved areas, and sidewalk from parking lot)	1.2 acres
Common area driveway and parking lot	0.7 acres
Total impervious areas	2.7 acres

Thus, 2.7 acres of the 3 acre common area, located in Area A, is covered by impervious surfaces. $I_{A\ common\ areas}$ = 2.7 acres

Step 3: Calculate the % impervious area (I) for each drainage area of the site using Equation 2-5. Because the water quality buffer is entirely undisturbed, and therefore entirely pervious, it is not considered in the calculation.

For Area A:

$I_A = ((I_{A\ residential\ areas} + I_{A\ common\ areas}) \div 12\ \text{acres}) \times 100\%$
$I_A = ((1.23\ \text{acres} + 2.7\ \text{acres}) \div 12\ \text{acres}) \times 100\%$
$I_A = (3.9\ \text{acres} \div 12\ \text{acres}) \times 100\%$
$I_A = 32.8\%$

For Area B:

$I_B = (I_{B\ residential\ areas} \div 19\ \text{acres}) \times 100\%$
$I_B = (4.94\ \text{acres} \div 19\ \text{acres}) \times 100\%$
$I_B = 26.0\%$

Therefore, the % impervious area for Area A (I_A) for the site is 32.8%. The % impervious area for Area B (I_B) is 26.0%. These values are utilized in Equation 2-2 to determine the values of Rv which will then be used in Equation 2-1 to find the WQv for each stormwater quality treatment BMP on the site.

2.2.6 Reducing the WQv

One of the key points to remember when calculating WQv is that it is proportional to impervious area, such that the amount of stormwater runoff required for treatment increases as impervious area increases. In other words, the more you pave, the more you treat. Therefore, to reduce the amount of stormwater runoff that must be treated, the developer must find ways to reduce site imperviousness. Reductions in imperviousness are beneficial from a stormwater management standpoint. Decreases in impervious area equate to less runoff, lower post-development peak discharges, and typically lower pollutant discharges. This can result in lower stormwater management costs, as structural BMPs, channel protection, and flooding protection controls can be smaller in size.

In order to reduce the WQv for a development site, Knox County encourages the use of better site design practices. Better site design can be defined as a combination of non-structural design approaches intended to reduce the impacts of stormwater runoff from development through the conservation of natural areas, reduction of impervious areas, and integration of stormwater treatment BMPs. Such practices are often referred to as “non-structural practices or BMPs”. By implementing a combination of these non-structural approaches, it is possible to reduce the amount of runoff and pollutants that are generated from a site and provide for some non-structural on-site treatment and control of runoff.

Knox County does not require the use of better site design practices on a development or redevelopment site to attain the 80% TSS removal standard. However, in accordance with Minimum Standard #2 (Chapter 1), a strong incentive for the use of such practices is provided via the WQv method and through WQv credits. The basic premise of the credit system is to recognize the water quality benefits of certain site design practices by allowing for a reduction in the WQv. The WQv credits that are available in Knox County are listed in Table 2-4. Detailed policies and design requirements for credits and better site design practices are presented in Volume 2, Chapter 5 of this manual.

Table 2-4. Summary of WQv Credits

Credit	Description
Credit 1: Natural area preservation	Undisturbed natural areas are conserved, thereby retaining the pre-development hydrologic and water quality characteristics.
Credit 2: Managed area preservation	Managed areas of open space are preserved, reducing total site runoff and retaining near pre-development hydrologic and water quality characteristics.
Credit 3: Stream and vegetated buffers	Stormwater runoff is treated by directing sheet flow runoff through a naturally vegetated or forested buffer as overland flow.
Credit 4: Vegetated channels	Vegetated channels are used to provide stormwater treatment.
Credit 5: Impervious area disconnection	Overland flow filtration/infiltration zones are incorporated into the site design to receive runoff from rooftops and other small impervious areas.
Credit 6: Environmentally sensitive large lot neighborhood	A group of site design techniques are applied to low and very low density residential development.