

# ADDRESSING STORMWATER MANAGEMENT NEEDS

## 1.1 Impacts of Development and Stormwater Runoff

Land development changes not only the physical, but also the chemical and biological conditions of Knox County's streams. This chapter describes the changes that occur due to development and the resulting stormwater runoff impacts.

### 1.1.1 Development Changes Land and Runoff

When land is developed, the hydrology, or the natural cycle of water is disrupted and altered. Clearing removes the vegetation that intercepts, slows and returns rainfall to the air through evaporation and transpiration. Grading flattens hilly terrain and fills in natural depressions that slow and temporarily store stormwater runoff. The topsoil and sponge-like layers of decaying leaves and other organic materials are scraped and removed and the remaining subsoil is compacted. Rainfall that once seeped into the ground now runs off the surface. The addition of buildings, roadways, parking lots and other surfaces that are impervious to rainfall further reduces infiltration and increases runoff.

Depending on the magnitude of changes to the land surface, the total runoff volume can increase dramatically. These changes not only increase the total volume of runoff, but also accelerate the rate at which runoff flows across the land. This effect is further exacerbated by drainage systems such as gutters, storm sewers and lined channels that are designed to quickly carry runoff to rivers and streams.

Development and impervious surfaces also reduce the amount of water that infiltrates into the soil and groundwater, thus reducing the amount of water that can recharge aquifers and feed streamflow during periods of dry weather.

Finally, development and urbanization affect not only the quantity of stormwater runoff, but also its quality. Development increases both the concentration and types of pollutants carried by runoff. As it runs over rooftops and lawns, parking lots and industrial sites, stormwater picks up and transports a variety of contaminants and pollutants to downstream waterbodies. The loss of the original topsoil and vegetation removes a valuable filtering mechanism for stormwater runoff.

The cumulative impact of development and urban activities, and the resultant changes to both stormwater quantity and quality in the entire land area that drains to a stream, river, lake or estuary determines the conditions of the waterbody. This land area that drains to the waterbody is known as its *watershed*. Urban development within a watershed has a number of direct impacts on downstream waters and waterways. These impacts include:

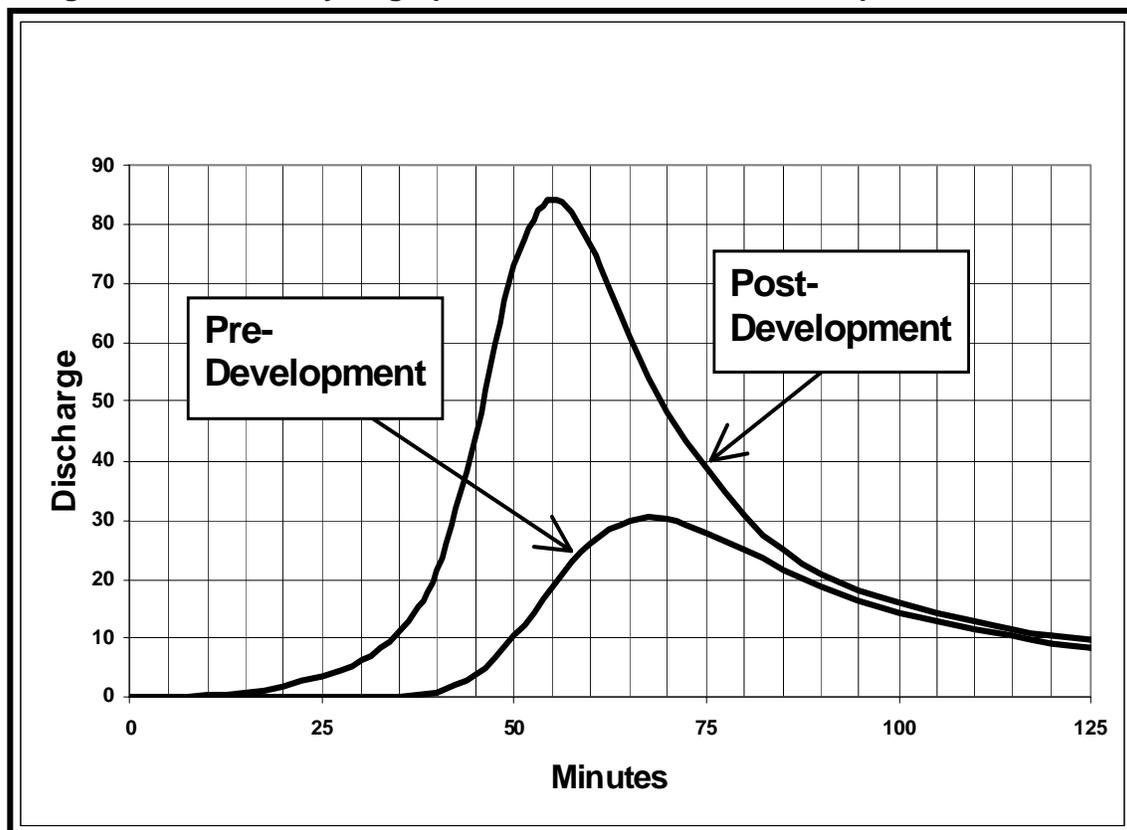
- Changes to stream flow;
- Changes to stream geometry;
- Degradation of aquatic habitat; and,
- Water quality impacts.

### 1.1.2 Changes to Stream Flow

Urban development alters the hydrology of watersheds and streams by disrupting the natural water cycle. This results in:

- Increased Runoff Volumes – Land surface changes can dramatically increase the total volume of runoff generated in a developed watershed.
- Increased Peak Runoff Discharges – Increased peak discharges for a developed watershed can be two to five times higher than those for a watershed prior to development. This is depicted in Figure 1-1.
- Greater Runoff Velocities – Impervious surfaces and compacted soils, as well as improvements to the drainage system such as storm drains, pipes and ditches, increase the speed at which rainfall runs off land surfaces within a watershed.
- Timing – As runoff velocities increase, it takes less time for water to run off the land and reach a stream or other waterbody.
- Increased Frequency of Bankfull and Near Bankfull Events – Increased runoff volumes and peak flows increase the frequency and duration of smaller bankfull and near bankfull events which are the primary channel forming events.
- Increased Flooding – Increased runoff volumes and peaks also increase the frequency, duration and severity of out-of-bank flooding.
- Lower Dry Weather Flows (Baseflow) – Reduced infiltration of stormwater runoff causes streams to have less baseflow during dry weather periods and reduces the amount of rainfall recharging groundwater aquifers.

**Figure 1-1. Runoff Hydrograph under Pre- and Post-Development Conditions**

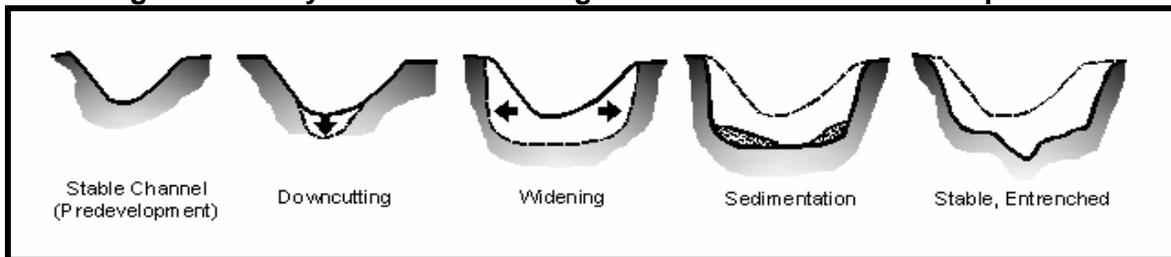


### 1.1.3 Changes to Stream Geometry

The changes in the rates and amounts of runoff from developed watersheds directly affect the morphology, or physical shape and character, of Tennessee's creeks and streams. This is depicted graphically in Figure 1-2. Some of the impacts due to urban development include:

- Stream Widening and Bank Erosion – Stream channels widen to accommodate and convey the increased runoff and higher stream flows from developed areas. More frequent small and moderate runoff events undercut and scour the lower parts of the streambank, causing the steeper banks to slump and collapse during larger storms. Higher flow velocities further increase streambank erosion rates. A stream can widen many times its original size due to post-development runoff.
- Stream Downcutting – Another way that streams accommodate higher flows is by downcutting their streambed. This causes instability in the stream profile, or elevation along a stream's flow path, which increases velocity and triggers further channel erosion both upstream and downstream.
- Loss of Riparian Tree Canopy – As streambanks are gradually undercut and slump into the channel, the trees that had protected the banks are exposed at the roots. This leaves them more likely to be uprooted during major storms, further weakening bank structure.
- Changes in the Channel Bed Due to Sedimentation – Due to channel erosion and other sources upstream, sediments are deposited in the stream as sandbars and other features, covering the channel bed, or substrate, with shifting deposits of mud, silt and sand.
- Increase in the Floodplain Elevation – To accommodate the higher peak flow rate, a stream's floodplain elevation typically increases following development in a watershed due to higher peak flows. This problem is compounded by building and filling in floodplain areas, which cause flood heights to rise even further. Property and structures that had not previously been subject to flooding may now be at risk.

**Figure 1-2. Physical Stream Changes Due to Watershed Development**



### 1.1.4 Impacts to Aquatic Habitat

Along with changes in stream hydrology and morphology, the habitat value of streams diminishes due to development in a watershed. Impacts on habitat include:

- Degradation of Habitat Structure – Higher and faster flows due to development can scour channels and wash away entire biological communities. Streambank erosion and the loss of riparian vegetation reduce habitat for many fish species and other aquatic life, while sediment deposits can smother bottom-dwelling organisms and aquatic habitat.
- Loss of Pool-Riffle Structure – Streams draining undeveloped watersheds often contain pools of deeper, more slowly flowing water that alternate with “riffles” or shoals of shallower, faster flowing water. These pools and riffles provide valuable habitat for fish and aquatic insects. As a result of the increased flows and sediment loads from urban watersheds, the pools and riffles disappear and are replaced with more uniform, and often shallower, streambeds that provide less varied aquatic habitat.

- Decline of Abundance and Biodiversity – When there is a reduction in various habitats and habitat quality, both the number and the variety, or diversity, of organisms (wetland plants, fish, macroinvertebrates, etc.) are also reduced. Sensitive fish species and other life forms disappear and are replaced by those organisms that are better adapted to the poorer conditions. The diversity and composition of the benthic, or streambed, community have frequently been used to evaluate the quality of urban streams. Aquatic insects are a useful environmental indicator as they form the base of the stream food chain.

Fish and other aquatic organisms are impacted not only by the habitat changes brought on by increased stormwater runoff quantity, but are often also adversely affected by water quality changes due to development and resultant land use activities in a watershed.

### 1.1.5 Water Quality Impacts

Nonpoint source pollution, which is the primary cause of polluted stormwater runoff and water quality impairment, comes from many diffuse or scattered sources, many of which are the result of human activities within a watershed. Development concentrates and increases the amount of these nonpoint source pollutants. As stormwater runoff moves across the land surface, it picks up and carries away both natural and human-made pollutants, depositing them into Knox County's streams, rivers, lakes, wetlands, and groundwater. Nonpoint source pollution is the leading source of water quality degradation in Knox County. According to the State of Tennessee's list of impaired waters, sediment and habitat alteration are considered two major pollutants for streams in Knox County.

Water quality degradation in urbanizing watersheds starts when development begins. Erosion from construction sites and other disturbed areas contribute large amounts of sediment to streams. As construction and development proceed, impervious surfaces replace the natural land cover and pollutants from human activities begin to accumulate on these surfaces. During storm events, these pollutants are then washed off into the streams. Stormwater also causes discharges from sewer overflows and leaching from septic tanks. There are a number of other causes of nonpoint source pollution in urban areas that are not specifically related to wet weather events including leaking sewer pipes, sanitary sewage spills, and illicit discharge of commercial/industrial wastewater and wash waters to storm drains.

Due to the magnitude of the problem it is important to understand the nature and sources of urban stormwater pollution. Table 1-1 summarizes the major stormwater pollutants and their effects. Some of the most frequently occurring pollution impacts to urban streams and their sources are:

- Reduced Oxygen in Streams – The decomposition process of organic matter uses up dissolved oxygen (DO) in the water, which is essential to fish and other aquatic life. As organic matter is washed off by stormwater, dissolved oxygen levels in receiving waters can be rapidly depleted. If the DO deficit is severe enough, fish kills may occur and stream life can weaken and die. In addition, oxygen depletion can affect the release of toxic chemicals and nutrients from sediments deposited in a waterway.

All forms of organic matter in urban stormwater runoff such as leaves, grass clippings and pet waste contribute to the problem. In addition, there are a number of non-stormwater discharges of organic matter to surface waters such as sanitary sewer leakage and septic tank leaching.

- Microbial Contamination – The level of bacteria, viruses and other microbes found in urban stormwater runoff often exceeds public health standards for water contact recreation such as swimming and wading. Microbes can also contaminate shellfish beds, preventing their harvesting and consumption and increasing the cost of treating drinking water. The main sources of these contaminants are sewer overflows, septic tanks, pet waste, and urban wildlife such as pigeons, waterfowl, squirrels, and raccoons.

**Table 1-1. Major Stormwater Pollutants and Their Potential Effects**

| Constituents  | Effects  |
|---|--|
| <b>Sediments</b> - Suspended Solids, Dissolved Solids, Turbidity  | Stream turbidity<br>Habitat changes<br>Recreation/aesthetic loss<br>Contaminant transport<br>Filling of lakes and reservoirs |
| <b>Nutrients</b> - Nitrate, Nitrite, Ammonia, Organic Nitrogen, Phosphate, Total Phosphorus                         | Algae blooms<br>Eutrophication<br>Ammonia and nitrate toxicity<br>Recreation/aesthetic loss                                  |
| <b>Microbes</b> - Fecal Coliforms, Fecal Streptococci, Viruses, E.Coli, Enterocci                                   | Ear/intestinal infections<br>Shellfish toxicity<br>Recreation/aesthetic loss   |
| <b>Organic Matter</b> - Vegetation, Sewage, Other Oxygen Demanding Materials  | Dissolved oxygen depletion<br>Odors<br>Fish kills  |
| <b>Toxic Pollutants</b> - Heavy Metals (cadmium, copper, lead, zinc), Organics, Hydrocarbons, Pesticides/Herbicides | Human & aquatic toxicity<br>Bioaccumulation in the food chain  |
| <b>Thermal Pollution</b>  | Dissolved oxygen depletion<br>Habitat changes  |
| <b>Trash and debris</b>   | Recreation/aesthetic loss  |

- **Nutrient Enrichment** – Runoff from urban watersheds contains increased nutrients such as nitrogen or phosphorus compounds. Increased nutrient levels are a problem as they promote weed and algae growth in lakes, streams and estuaries. Algae blooms block sunlight from reaching underwater grasses and deplete oxygen in bottom waters. In addition, nitrification of ammonia by microorganisms can consume dissolved oxygen, while nitrates can contaminate groundwater supplies. Sources of nutrients in the urban environment include washoff of fertilizers and vegetative litter, animal wastes, sewer overflows and leaks, septic tank seepage, detergents, and the dry and wet fallout of materials in the atmosphere.
- **Hydrocarbons** – Oils, greases and gasoline contain a wide array of hydrocarbon compounds, some of which have shown to be carcinogenic, tumorigenic and mutagenic in certain species of fish. In addition, in large quantities, oil can impact drinking water supplies and affect recreational use of waters. Oils and other hydrocarbons are washed off roads and parking lots, primarily due to leakage from vehicle engines. Other sources include the improper disposal of motor oil in storm drains and streams, spills at fueling stations and restaurant grease traps.
- **Toxic Materials** – Besides oils and greases, urban stormwater runoff can contain a wide variety of other toxicants and compounds including heavy metals such as lead, zinc, copper, and cadmium, and organic pollutants such as pesticides, PCBs, and phenols. These contaminants are of concern because they are toxic to aquatic organisms and can bioaccumulate in the food chain. In addition, they also impair drinking water sources and human health. Many of these toxicants accumulate in the sediments of streams and lakes. Sources of these contaminants include industrial and commercial sites, urban surfaces such as rooftops and painted areas, vehicles and other machinery, improperly disposed household chemicals, landfills, hazardous waste sites and atmospheric deposition.



- **Sedimentation** – Eroded soils are a common component of urban stormwater and a pollutant in their own right. Excessive sediment can be detrimental to aquatic life by interfering with photosynthesis, respiration, growth and reproduction. Sediment particles transport other pollutants that are attached to their surfaces including nutrients, trace metals and hydrocarbons. High turbidity due to sediment increases the cost of treating drinking water and reduces the value of surface waters for industrial and recreational use. Sediment also fills ditches and small streams and clogs storm sewers and pipes, causing flooding and property damage. Sedimentation can reduce the capacity of reservoirs and lakes, block navigation channels, fill harbors and silt estuaries. Erosion from construction sites, exposed soils, street runoff, and streambank erosion are the primary sources of sediment in urban runoff.
- **Higher Water Temperatures** – As runoff flows over impervious surfaces such as asphalt and concrete, it increases in temperature before reaching a stream or pond. Water temperatures are also increased due to shallow ponds and impoundments along a watercourse as well as fewer trees along streams to shade the water. Since warm water can hold less dissolved oxygen than cold water, this “thermal pollution” further reduces oxygen levels in urban streams. Temperature changes can severely disrupt certain aquatic species, such as trout and stoneflies, which can survive only within a narrow temperature range.
- **Trash and Debris** – Considerable quantities of trash and other debris are washed through storm drain systems and into streams, lakes and bays. The primary impact is the creation of an aesthetic “eyesore” in waterways and a reduction in recreational value. In smaller streams, debris can cause blockage of the channel, which can result in localized flooding and erosion.

### 1.1.6 Stormwater Hotspots

Stormwater hotspots are areas of the urban landscape that often produce higher concentrations of certain pollutants, such as hydrocarbons or heavy metals, than are normally found in urban runoff. These areas merit special management and the use of specific pollution prevention activities and/or structural stormwater controls. The Director of the Knox County Department of Engineering and Public Works has the authority to require additional measures for developments and redevelopments that propose such hotspot land uses. Examples of stormwater hotspots include, but are not limited to:

- Gas/fueling stations
- Vehicle maintenance areas
- Vehicle washing / steam cleaning
- Auto recycling facilities
- Outdoor material storage areas
- Plant nurseries, agricultural areas
- Kennels, feed lots, etc.
- Loading and transfer areas
- Landfills
- Construction sites
- Industrial sites
- Industrial rooftops

### 1.1.7 Effects on Ponds, Lakes and Reservoirs

Stormwater runoff into ponds, lakes and reservoirs can have some unique negative effects. A notable impact of urban runoff is the filling in of lakes with sediment. Another significant water quality impact on lakes related to stormwater runoff is nutrient enrichment. This can result in the undesirable growth of algae and aquatic plants. Enclosed or regulated waterbodies such as ponds, lakes and reservoirs do not flush contaminants as quickly as streams and act as sinks for nutrients, metals and sediments. This means that lakes can take longer to recover if contaminated.

## 1.2 Addressing Stormwater Impacts

The focus of the Knox County stormwater management program is effective and comprehensive stormwater management. Stormwater management involves both the prevention and mitigation of stormwater runoff quantity and quality impacts as described in this chapter through a variety of methods and mechanisms.

Volume 2 of this manual provides requirements, policies, and guidance for developers in Knox County to effectively implement stormwater management controls on-site to address the potential impacts of new development and redevelopment, and both prevent and mitigate problems associated with stormwater runoff. This is accomplished by:

- Developing land in a way that minimizes its impact on a watershed by reducing both the amount of runoff and the pollutants generated;
- Using the most current and effective erosion and sedimentation control practices during the *construction* phase of development;
- Controlling stormwater runoff peaks, volumes and velocities to prevent both downstream streambank channel erosion and flooding;
- Treating *post-construction* stormwater runoff before it is discharged to a waterway; and
- Implementing pollution prevention practices to prevent stormwater from becoming contaminated in the first place.

The remainder of Chapter 1 outlines the minimum stormwater management standards that Knox County uses to guide the requirements, policies and incentives of the stormwater management program.

### 1.3 Comprehensive Stormwater Management Planning

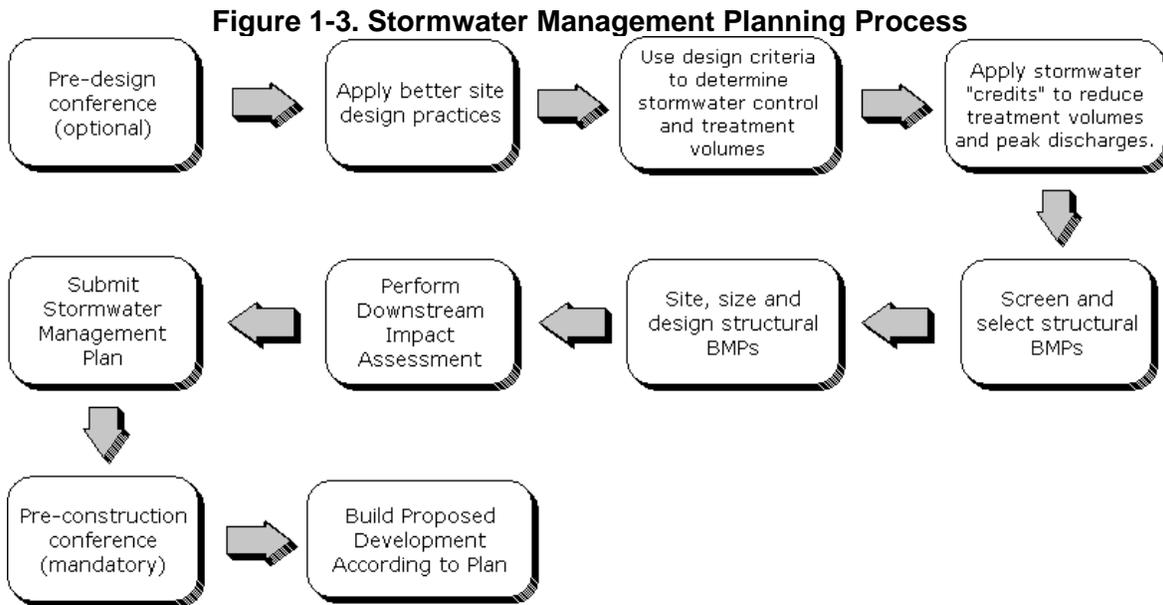
This section presents a comprehensive and integrated set of stormwater management standards for new development and redevelopment projects in Knox County. Minimum standards and performance requirements for controlling runoff from development are critical to addressing both the water quantity and quality impacts of post-construction urban stormwater and are required of Knox County in order to comply with National Pollutant Discharge Elimination System (NPDES) stormwater regulations. Minimum stormwater management standards must also be supported by a set of design and management tools and an integrated design approach for implementing both structural and nonstructural stormwater controls. The major elements of Knox County's stormwater management program are:

- Incentives for Stormwater Better Site Design – The first step in addressing stormwater management begins with the site planning and design process. The goals of better site development design are to reduce the amount of runoff and pollutants that are generated from a development site and provide for some nonstructural on-site treatment and control of runoff by implementing a combination of approaches collectively known as *stormwater better site design practices*. These include maximizing the protection of natural features and resources on a site, developing a site design that minimizes impact, reducing overall site imperviousness, and utilizing natural systems for stormwater management. General guidance on the types and application of better site design practices is provided in Volume 2, Chapter 5 of this manual.
- Stormwater Credits for Better Site Design – Knox County has developed a set of stormwater "credits" that can be used to provide developers and site designers' incentives to implement better site design practices that can reduce the volume of stormwater runoff and minimize the pollutant loads from a site. While reducing stormwater impacts, the credit system can also translate directly into cost savings to the developer by reducing the size of structural stormwater control and conveyance facilities. Specific technical guidance on the stormwater credits offered by Knox County is presented in Volume 2, Chapter 5 of this manual.
- Integrated Stormwater Design Criteria – The Integrated Stormwater Design (ISD) criteria is a combination of design criteria for stormwater quantity and quality management which addresses the entire range of hydrologic events. These criteria allow the site engineer to calculate the stormwater control volumes required for water quality, downstream channel

protection, and overbank and extreme flood protection. Specific technical guidance on stormwater design criteria is presented in Volume 2, Chapter 2 of this manual.

- Downstream Impact Analysis – Downstream peak discharge analyses are required to ensure that a proposed development is not adversely impacting downstream properties after the on-site stormwater management requirements have been addressed. These analyses can potentially be used to modify the requirement for overbank and extreme flood control, should the analysis reveal that such stormwater control measures would cause a negative flood impact on downstream properties. Downstream impact analysis requirements are presented in the Knox County Stormwater Management Ordinance and in Volume 2, Chapter 2 of this manual.
- Guidance on Structural Stormwater Controls – This manual provides requirements and specifications for a set of structural stormwater controls that can be used to meet Knox County’s stormwater management water quantity and quality goals. Specific technical guidance on how to select, size, design, construct and maintain structural controls is provided in Volume 2, Chapter 4 of this manual.
- Stormwater Management Plan – Knox County requires the preparation of a Stormwater Management Plan for development and redevelopment activities. The plan must be approved by Knox County Engineering, prior to obtaining a grading or building permit. The purpose, requirements, and contents for this plan are discussed in Volume 1 of this manual.

Figure 1-3 illustrates how these design tools will be used in the development process to address Knox County’s stormwater management requirements.



## 1.4 Minimum Stormwater Management Standards

This section presents a set of minimum performance standards for stormwater management for development activities in Knox County. These performance standards provide an integrated approach to address both the water quality and quantity problems associated with stormwater runoff due to urban development. They are designed to assist Knox County government in complying with regulatory and programmatic requirements for various State and Federal programs including the National Pollutant Discharge Elimination System (NPDES), Municipal Separate Storm Sewer System (MS4) permit program and the National Flood Insurance Program (NFIP) under the Federal Emergency Management Agency (FEMA).

These minimum standards are provisions of Knox County's Stormwater Management Ordinance and are implemented and supported by the Stormwater Management Manual and Knox County's plans review process. The goal of these stormwater management requirements for areas of new development and redevelopment is to reduce the impact of post-construction stormwater runoff quality and quantity on the watershed. This can be achieved by:

- Maximizing the use of better site design and nonstructural methods to reduce the generation of runoff and pollutants;
- Managing and treating stormwater runoff through the use of structural stormwater controls; and,
- Implementing pollution prevention practices to limit potential stormwater contaminants.

The minimum stormwater management standards presented here incorporate these concepts and cover the entire cycle of development from site planning through long-term maintenance of stormwater management facilities after construction has been completed.

The following standards are the minimum stormwater management performance requirements for new development or redevelopment sites that must submit a stormwater management plan. A detailed explanation of each minimum standard is presented elsewhere in this manual, as noted in italics at the end of the standard title.

#### **Minimum Standard #1 – Stormwater Quality Treatment** (*Volume 2, Chapter 2*)

Stormwater runoff from development and redevelopment shall be treated to remove pollutants prior to discharge from the development or redevelopment site. Stormwater management systems shall be designed to remove 80% of the post-development total suspended solids (TSS) load, based on the 85<sup>th</sup> percentile storm event, and be able to meet any other additional watershed or site-specific water quality requirements, as determined by Knox County Engineering. The justification for this standard is presented later in this chapter. Design criteria and equations are presented in Chapter 2. It is presumed that a stormwater management system complies with this performance standard if:

- Appropriate structural stormwater controls are selected, designed, constructed, and maintained according to the specific criteria in this manual; and
- Runoff from hotspot land uses and activities is adequately treated and addressed through the use of appropriate structural stormwater controls and pollution prevention practices.

#### **Minimum Standard #2 – Use of Better Site Design Practices** (*Volume 2, Chapter 5*)

Knox County will give stormwater "credits" for new developments and redevelopments to encourage the use and *Better Site Design* practices, promote the maximum preservation of natural and connected open space within and between developments, and provide additional opportunities for stormwater treatment.

#### **Minimum Standard #3 – Stream Channel Protection** (*Volume 2, Chapter 2*)

Stream channel protection shall be provided through the capture and extended detention of the runoff volume from the 1-year return frequency, 24-hour duration storm event.

#### **Minimum Standard #4 – Overbank Flood Protection** (*Volume 2, Chapter 2*)

Overbank flood protection shall be provided such that the calculated peak discharge of stormwater runoff resulting from the 2-year, 10-year, and 25-year return frequency, 24-hour duration storm events shall be no greater after development or redevelopment of the site than that which would result from the same 2-year, 10-year, and 25-year return frequency, 24-hour duration storms on the same site prior to development or redevelopment. Minimum standard



#4 can be modified in the event that a downstream impact analysis indicates that negative downstream flood impacts will result from on-site peak discharge controls.

**Minimum Standard #5 – Extreme Flood Protection** (*Volume 2, Chapter 2*)

Extreme flood protection shall be provided such that the calculated peak discharge of stormwater runoff resulting from a 100-year frequency, 24-hour duration storm shall be no greater after development or redevelopment of the site than that which would result from a 100-year frequency, 24-hour duration storm on the same site prior to development or redevelopment. Minimum standard #5 can be modified in the event that a downstream impact analysis indicates that negative downstream flood impacts will result from on-site peak discharge controls.

**Minimum Standard #6 – Downstream Impact Analysis** (*Volume 2, Chapter 2*)

A downstream hydrologic analysis shall be performed to determine if the proposed development or redevelopment causes an increase in peak discharge while meeting Minimum Standards #4 and #5. This analysis shall be performed at the outlet(s) of the site, and downstream at each tributary junction to the point(s) in the conveyance system where the area of the portion of the site draining into the system is less than or equal to 10% of the total drainage area above that point. Downstream flood protection shall be provided where the downstream impact analysis indicates peak discharge increases.

**Minimum Standard #7 – Erosion Prevention and Sediment Control** (*Volume 2, Chapter 9*)

Erosion prevention and sedimentation control (EPSC) practices shall be utilized during the construction phase or during any land disturbing activities. In general, Knox County requires that owners and operators of construction sites implement EPSC practices in accordance with the regulations and design and maintenance standards stated in the State of Tennessee General NPDES Permit for Discharges of Stormwater Associated with Construction Activities (also called the NPDES Construction General Permit), and the *Tennessee Erosion and Sediment Control Handbook*.

**Minimum Standard #8 – BMP Operation and Maintenance** (*Volume 1, Chapter 4*)

The owner(s) of stormwater management facilities and/or best management practices shall at all times properly operate and maintain all facilities and systems of stormwater treatment and control (and related appurtenances), and all best management practices in such a manner as to maintain the full function of the facilities or best management practices which are installed or used by the property owner(s) to achieve compliance with this ordinance.

**Minimum Standard #9 – Pollution Prevention** (*Volume 2, Chapter 10*)

New developments and redevelopments shall implement pollution prevention practices during and after development of the site. A Special Pollution Abatement Permit shall be required for land uses that are typically known to have a higher than normal potential for discharge of pollutants.

**Minimum Standard #10 – Development In and Around Sinkholes** (*Volume 2, Chapter 8*)

Developments and redevelopments that have sinkholes located entirely or partially on-site shall satisfy the design requirements for Minimum Standards #4 and #5. Developments and redevelopments that drain to sinkholes shall implement retention or detention of stormwater runoff such that the post-development peak discharges do not exceed pre-development discharges.

**Minimum Standard #11 – Protection Using Water Quality Buffers** (*Volume 2, Chapter 6*)

Water quality buffers shall be established, protected and maintained along all community waters, which includes streams, ponds, lakes and wetlands in Knox County.

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**Minimum Standard #12 – Stormwater Management Plan** (*Volume 1, Chapter 4*)

The development project shall prepare a stormwater management plan for review by Knox County Engineering that presents the methods used to address Minimum Standards #1 through #11 in the proposed development or redevelopment.

## 1.5 Stormwater Quality Treatment Rationale

This section provides an explanation of Minimum Standard #1, which requires 80% removal of total suspended solids (TSS) from post-construction stormwater runoff based on capture of the 85th percentile storm event.

### 1.5.1 Regulatory Overview

The NPDES Phase II regulation requires that Knox County (and other Phase II regulated communities) develop, implement, and enforce a stormwater management program that reduces the discharge of pollutants from the regulated jurisdiction “to the maximum extent practicable (MEP)”. MEP is a technology-based discharge standard that was designed for the reduction of pollutant discharges and established in the Clean Water Act. Using guidance provided by the Environmental Protection Agency (EPA), Knox County can achieve the MEP standard by instituting a stormwater management program that implements and requires best management practices (BMPs) that are designed to protect water quality. No further guidance on MEP is provided by EPA or by the Tennessee Department of Environment and Conservation (TDEC).

Control measure 5 of the National Pollutant Discharge Elimination System (NPDES) Phase II Permit presents the requirements for the control of post-construction (i.e., after development) stormwater runoff. Quoting directly from the NPDES Permit for the State of Tennessee, regulated cities and counties (including Knox County) must:

*“Develop, implement, and enforce a program to address storm water runoff from new development and redevelopment projects that disturb greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale, that discharge into your small MS4. Your program must ensure that controls are in place that would prevent or minimize water quality impacts;*

*Develop and implement strategies which include a combination of structural and/or non-structural best management practices appropriate for your community; and*

*Develop and implement a set of requirements to establish, protect and maintain water quality buffers in areas of new development and redevelopment.*

*Use an ordinance or other regulatory mechanism to address post-construction runoff from new development and redevelopment projects to the extent allowable under State or local law.”*

As a result of these requirements, Knox County must implement a requirement for new developments and redevelopments to control stormwater quality using both structural (i.e., constructed) and non-structural (i.e., site planning) best management practices (BMPs). This requirement must be fully implemented no later than 2008.

The NPDES Phase II regulation also requires that Knox County focus stormwater management on controlling discharges of pollutants of concern to local impaired streams. Based on the State of Tennessee’s 303(d) list of “impaired” streams, the largest pollutant in Knox County is sedimentation. In 2004, over 225 stream miles were considered impaired due to excessive sedimentation.

## 1.5.2 Attaining the Water Quality Standard

The basic goal of the NPDES Phase II regulation is to reduce the water quality impacts of development. The preferred approach to meet this goal and comply with the NPDES permit is called the “Water Quality Volume method” or “WQv method”. The WQv method is based on a minimum water quality control goal of 80% removal of TSS for the 85<sup>th</sup> percentile storm event from post-construction stormwater runoff (i.e., after construction of a site is completed). TSS is a commonly used representative stormwater pollutant for measuring sedimentation.

There are a number of factors that support the use of an 80% TSS removal standard as a minimum level water quality goal in Knox County.

1. The Tennessee 303(d) list indicates that sedimentation (i.e., sediment) is a significant pollutant of concern in local streams. This fact alone requires that Knox County implement a stormwater management program that, at least in part, focuses on the removal of sediment from stormwater discharges in order to achieve compliance with the NPDES Phase II regulations to the maximum extent practicable.
2. The use of TSS as an “indicator” pollutant for sediment is well-established.
3. The control of TSS leads to indirect control of other pollutants of concern that can adhere to suspended solids in stormwater runoff. In fact, some research shows that a large fraction of many other pollutants of concern are either reduced along with TSS, or at rates proportional to the TSS reduction.
4. A treatment standard of 80% is not a numeric standard, but a “best available technology” standard. In other words, the 80% TSS removal level is reasonably attainable using properly designed, constructed and maintained structural stormwater BMPs (for typical ranges of TSS concentration found in stormwater runoff). This standard is supported with research data from numerous research projects and compiled by the International Stormwater Best Management Practices (BMP) Database evaluation project, titled Determining Urban Stormwater Best Management Practices Removal Efficiencies, June, 2000.

The WQv method can meet the goal of 80% TSS removal using a two-pronged approach. First, it encourages the reduction of imperviousness (and therefore pollution) from developed sites through incentives for non-structural BMPs, such as natural conservation areas and water quality buffers. Second, it requires treatment of any remaining stormwater runoff with structural controls. This method allows Knox County to meet its water quality goals and regulatory requirements, yet still allows developers flexibility in their site designs.

There are a number of advantages with the WQv method when compared to the County’s current requirement for first flush treatment. These advantages are as follows:

- The WQv method provides a measure of flexibility in site design. The new development or redevelopment site will be required to meet the 80% reduction goal using one or more of a number of locally-acceptable structural BMPs.
- If desired, the developer can also utilize non-structural controls to reduce imperviousness. The WQv method will provide incentives for the reduction of impervious surfaces and the use of non-structural BMPs, such as buffers, natural space preservation, and impervious area disconnection. When utilized, these practices will reduce the amount of stormwater runoff that will require treatment by structural practices, thereby reducing the structural BMP maintenance burden.
- WQv is not a prescriptive approach in that it does not mandate the use of one specific treatment BMP, such as a first flush pond. Instead, the developer can choose from a menu of BMPs, each of which is assigned a % TSS removal efficiency. When constructed alone, or in combination with other structural and/or non-structural BMPs, the minimum percent TSS removal standard can be attained.

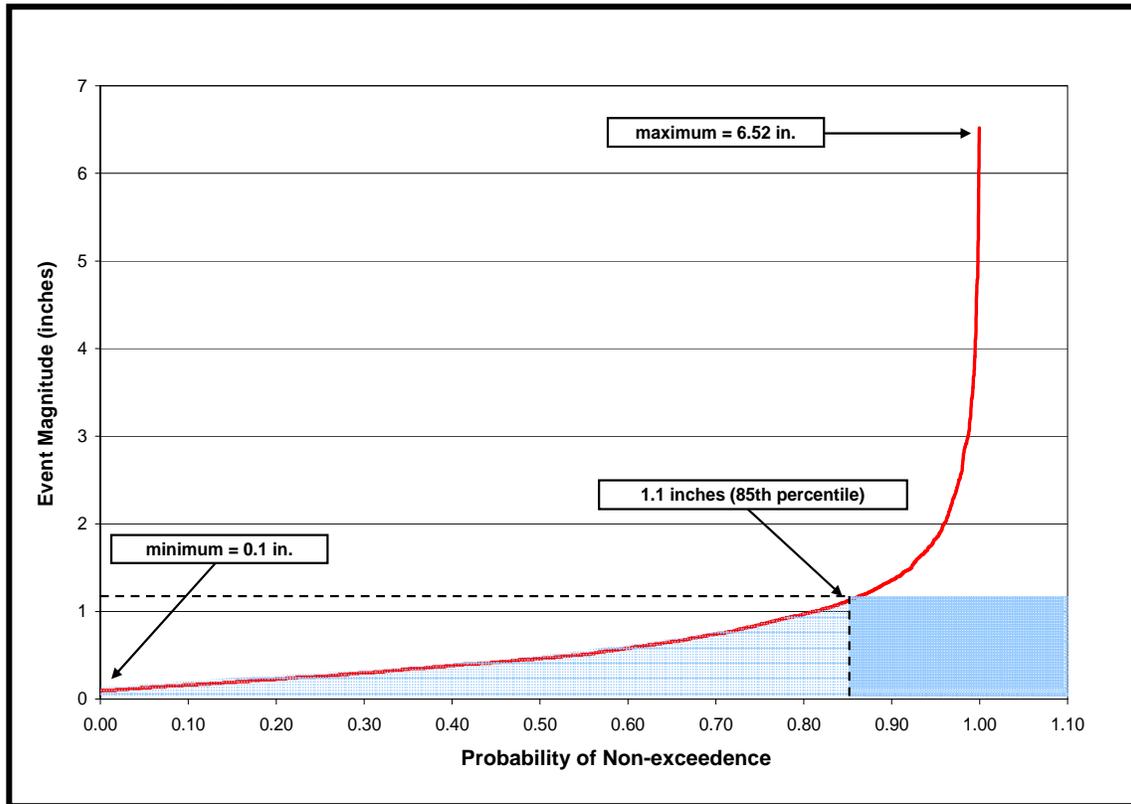
- Research shows that extended release “first flush” ponds, which are often called dry extended detention (ED) ponds and are commonly used in East Tennessee, cannot attain a TSS removal standard of 80%. Such ponds have a high propensity for sediment resuspension and subsequent discharges, especially during large storm events. Recent studies of the BMP give it an average TSS reduction somewhere between 50% and 70% (Schueler and Holland, 2000). Of course, pollutant removal ability does depend upon geographic location, overall sediment characteristics, hydrology, and storm event size.
- WQv is a performance based approach. If the BMP(s) are designed, constructed and maintained in accordance with guidance and requirements set by Knox County, then the BMP(s) will be considered “in compliance” with the minimum 80% water quality standard.
- The WQv method allows a consistent, “apples-to-apples” application of water quality treatment practices on every development site. Each site will be required to design, construct and maintain in accordance with the 80% TSS removal goal.

The WQv is calculated for the 85<sup>th</sup> percentile storm event using a value of 1.1 inches of rainfall. Thus, a stormwater management system designed for the WQv will treat the runoff from all storm events of 1.1 inches or less, as well as the first 1.1 inches of runoff for all larger storm events. The 85<sup>th</sup> percentile was chosen because it represents the “knee in the curve” volume that captures a significant number of storms (normally in the 80-90% of all storms range) without attempting to treat the small percentage of much larger storms that result in large volumes of runoff. Such storms would be expensive to treat, are rare in occurrence, and typically diluted in pollution concentration. Figure 1-4 presents a graphical representation of how the 85<sup>th</sup> percentile rainfall depth was determined, using a “knee-in-the-curve” approach. The value of 1.1 inches for the 85<sup>th</sup> percentile storm was determined for Knox County based on analysis of rainfall data collected in south Knox County and in Oak Ridge dating back to 1943.

Detailed information on the calculation of the WQv and % TSS removal for a development or redevelopment site are presented in Volume 2, Chapter 2 of this manual.

It is important to note that Knox County is not alone in implementing an 80% TSS removal standard, or the WQv method. Many states, including Maryland, Massachusetts, North Carolina, Georgia, and Florida have set similar statewide TSS goals and have research data to support BMPs meeting this reduction goal. Further, a number of communities in Tennessee, the State of Georgia and the Commonwealth of Virginia have implemented a WQv type of method as the statewide water quality control approach. The BMP design and maintenance guidance from these states can be used and modeled as appropriate to implement a water quality control program that is appropriate to meet Knox County’s needs.

Figure 1-4: Knox County 85<sup>th</sup> Percentile Rainfall Analysis





## References

GeoSyntec Consultants, URS, et al. *Determining Urban Stormwater Best Management Practices Removal Efficiencies*. June, 2000.

Schueler T., and Holland, H. *The Practice of Watershed Protection*. Center for Watershed Protection (CWP), 2000.

## Suggested Reading

North Carolina Department of Environment and Natural Resources, *Stormwater Management Site Planning*. 1998



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