Chapter 8
OVERALL STORMWATER PLANNING

8.1 Objectives for Stormwater Planning

Stormwater planning is usually not perceived as a high priority by the public for several reasons. Flooding happens infrequently, and the benefits of stormwater planning are taken for granted whenever rain falls and flooding does not occur. Most people do not notice stormwater drainage systems, particularly if located underground or at the property edge. A stormwater drainage system is often considered as unimportant, inconvenient, or too expensive to construct. Problems result when a drainage system is undersized during design or not constructed according to plans.

The benefits of stormwater quality planning are difficult for most people to understand, with many common misunderstandings about natural creeks and streams. Grass clippings, leaves, mulch and other "natural" materials are often disposed into creeks and stormwater drainage systems, as some people do not understand that these materials do not benefit the creeks at all but actually consume the dissolved oxygen in the creek and change pH levels. It is commonly believed that fish in the creek will consume cooking grease, unwanted food from restaurants and grocery stores, sanitary sewer flows, and pet animal wastes; actually these materials severely deplete the dissolved oxygen, change pH levels, and frequently carry harmful bacteria and viruses. Urban areas with lots of streets and roads receive a constant uniform loading of gasoline exhaust particulates, dripping automotive fluids, particles from brake linings or tires, etc.

Stormwater planning and stormwater modeling are required by federal agencies such as FEMA (flooding control, flood insurance) and USEPA (pollution reduction goals, water quality targets). The difficult aspect of stormwater planning is that it requires forethought, goals, slow but steady progress, the coordinated efforts of many entities, and the efficient and intelligent use of time, energy and resources. The principal objectives for stormwater planning are:

- To protect human health and safety to the maximum extent practical.
- To minimize damage to private property and structures within the City of Knoxville.
- To minimize damage to streets, bridges, sidewalks, trails, parks, public utilities and drainage channels.
- To reduce expenditures of public money for constructing expensive flood control projects.
- To preserve and protect the natural creeks, streams and waterways within the City of Knoxville for the purposes of environmental preservation, human enjoyment and recreation, floodplain capacity, and property values.
- To protect stormwater quality for the intended level of designated use on each stream or creek, and to restore/enhance water quality as directed by the state of Tennessee or other authorities.
- To wisely spend time, energy and resources of city employees and city equipment in pursuit to best serve the interests of the citizens of Knoxville.

8.2 Stormwater Quantity and Quality Considerations

Historically, the goal of stormwater design has been to safely control and convey stormwater without flooding houses, buildings, streets and yards. The principal method is to select adequate sizes for ditches, drop inlets, pipes, culverts and bridges to allow peak flows to move downstream. Stormwater detention basins help to reduce the potential for flooding by slowing stormwater runoff response.

Over the last three decades, national attention has been focused on improving water quality of streams, lakes, rivers and wetlands. Today, stormwater quantity and quality design are equally important in terms of protecting the natural creeks and streams within the City of Knoxville, in addition to Fort Loudoun Lake (Tennessee River) and its two tributaries. Consideration of stormwater quality allows fish, aquatic wildlife, vegetation and other animals to thrive and flourish in the natural creeks and streams. Greenways and parks, enjoyed by many Knoxville citizens, are typically located near waterways and creeks; this allows many more people to become interested in the creeks and streams.

Quantity considerations (controlling peak flows and reducing flood damage) will continue to be a high priority. Peak flows and total runoff volume are heavily influenced by the total amount of impervious areas. As a watershed is urbanized and impervious areas increase, flooding and drainage issues become more important. Flooding may occur at locations where development has encroached upon the floodplain, two channels intersect, channel slope or roughness coefficients limit the channel conveyance, or the floodplain width has been restricted.

Quality considerations can be addressed by nonstructural and structural means in ways that are often subtle and unobtrusive. For instance, stormwater detention basins are also required to reduce pollution by having a minimum drawdown time of 24 hours and a maximum drawdown time of 72 hours. Detention basins must have trash racks to capture debris and floatable materials. Well-maintained grass channels will slow the process of erosion and also capture sediments. Floodplains can be preserved as buffer zones, by including them as parks and greenways. Reducing stormwater volumes and peak flows are generally beneficial to improving stormwater quality.

8.3 Open Versus Closed Systems

A major consideration in the preliminary phase of any development project is whether to design open or closed stormwater conveyance systems. An open drainage system is defined as having every portion of the channel exposed directly to the atmosphere, without any possibility of pressure flow. A closed drainage system (typically with pipe, culverts, drop inlets, manholes) is only exposed directly to the atmosphere at a few locations, so that pressure flow typically occurs during heavy storms.

The potential advantages of an open stormwater conveyance system:

- Inspection is much easier to perform for an open drainage system when compared to a closed drainage system. Obvious problems and poor performance can be observed in both dry conditions and wet conditions. Pictures can be taken for documentation.

- Maintenance of open drainage systems can usually be done with ordinary grading equipment, whereas a closed drainage system often requires OSHA confined-space procedures, artificial lighting, ladders, nonsparking tools, rescue team on standby, etc.
- An open drainage system is more conducive to natural vegetation and wildlife than a closed system. Trees, grass, shrubs and vegetation require open sunlight to grow. An open system contains dirt, soil and mud, which are primary habitats for many creatures.
- Open drainage systems allow groundwater recharge, infiltration of stormwater, and evaporation; thus an open drainage system is a more natural condition than a closed system.
- Open drainage systems typically have lower velocities, which will reduce downstream peak flows. Lower velocities at culvert entrances and outlets will help to limit scour and erosion.
- Open drainage systems allow more settling of particulates, absorption of dissolved chemicals into soils and vegetation, and more opportunity for trash/debris to be captured. Stormwater quality requirements, such as first flush treatment, can be incorporated.

Potential advantages of a closed stormwater conveyance system:

- A closed drainage system has less surface area that is dedicated to conveying stormwater, which allows more property to be used for other purposes.
- A closed drainage system may reduce erosion by limiting stormwater contact with erosive soils and steep slopes (although velocities may be increased at the system outlet).
- A closed drainage system is lined with impermeable material so that stormwater infiltration losses do not occur. This allows a closed system to be installed near buildings, foundations or other structures where an open system may not be desirable.

The City of Knoxville Engineering Department has a strong preference for open drainage systems. However, it is realized that open drainage systems may not be feasible for a particular development. Usually, the choice of an open or closed drainage system relies heavily upon the existing drainage systems for neighboring properties, the adjacent street drainage system, and distance to potential drainage outlets. Also, the available elevation difference on the property can influence the choice of systems, since gravity is the driving force for almost all stormwater drainage systems.

It is expected that the developer or landowner will weigh the potential benefits and costs of each system (open versus closed), and then make a reasonable choice. Since stormwater detention is required for most properties, the type of detention basin makes a large impact on the choice of an open or closed drainage system. Underground detention structures are not generally allowed in the City of Knoxville (as explained in the Knoxville BMP Manual, ST-08).

8.4 Minor and Major Drainage Systems

A minor drainage system consists of swales, ditches, gutters, inlets, pipes and other structural measures which are necessary to carry the 10-year storm. These elements are typically sized by Manning's equation or other types of flow design procedures to handle a specified storm.

Whenever possible, ditches and pipes are typically overdesigned by choosing somewhat larger sizes; differences in material costs for standard manufactured pipe sizes are small and inconsequential when compared to the benefits of a well-designed drainage system.

A major drainage system consists of overland relief swales, roadway sections, floodplains, depressions, detention basins, storage dams, natural streams and creeks, large box culverts, bridges and other features that carry large flows such as the 100-year storm event. Whether intentionally designed or not, a major drainage system will develop during the course of a large storm event. For a given development, the design engineer should always consider the effects of blockage, collapse or inadequate capacity for one or more of the key conveyance structures.

8.5 Watersheds and Regional Planning

Figure 8-1 shows the principal rivers that join at Knoxville, along with the approximate extent of the Knoxville city limits. Most of the creeks and streams in Knoxville flow to the Tennessee River (Fort Loudoun Lake), which is controlled by a large TVA concrete dam located approximately 40 miles downstream from Knoxville at Lenoir City (River Mile 602.3). The Holston River and French Broad River join together within the City of Knoxville to form the Tennessee River (River Mile 652.0). Along the northern edge of the city limits, Beaver Creek and its tributaries flow in a southwest direction to the Clinch River.

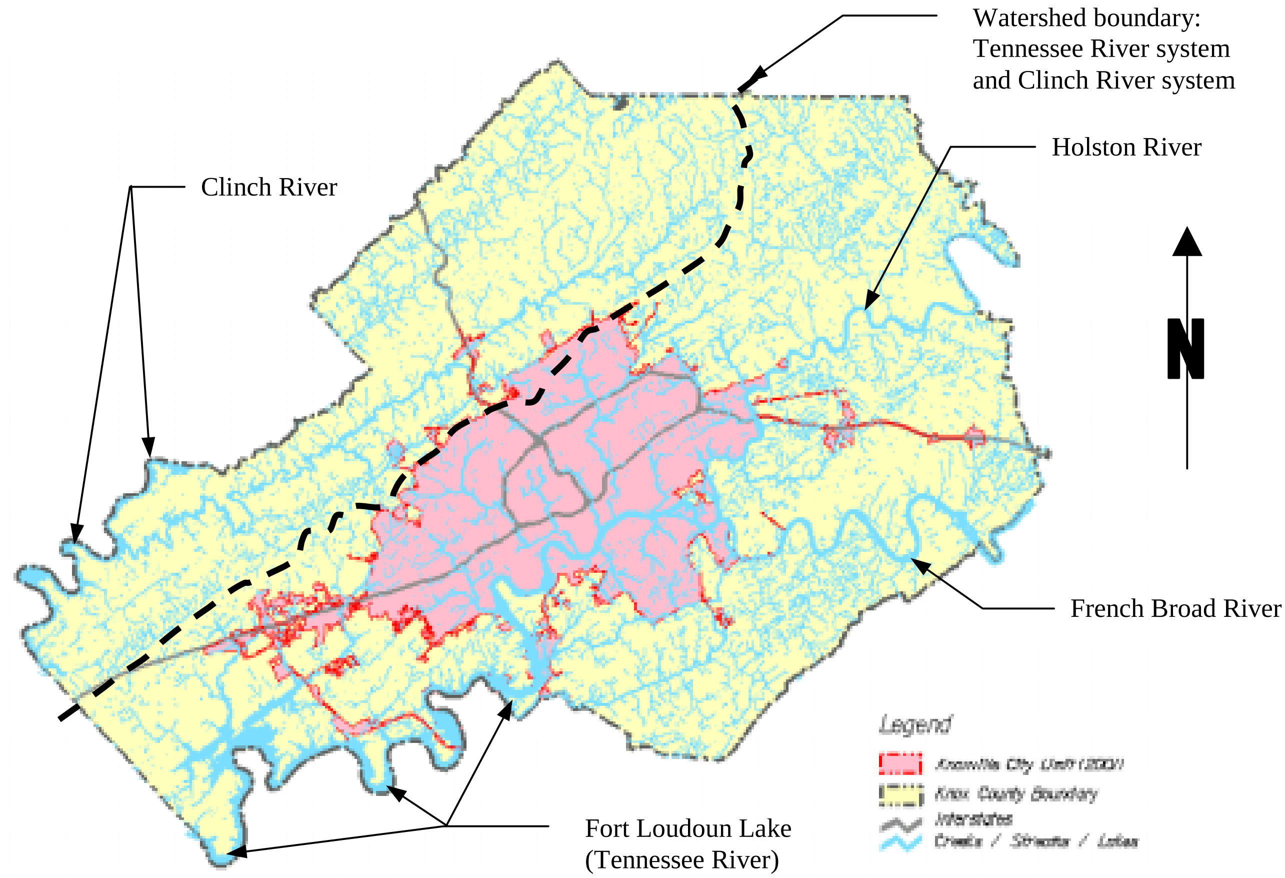

Figure 8-1
Knox County Drainage Overview

There are approximately 30 watersheds within the City of Knoxville for the purposes of stormwater monitoring and reporting. The NPDES permit issued to the City of Knoxville by the state of Tennessee requires that basic watershed sampling and analysis must be performed annually. Table 8-1 lists the watersheds within the City of Knoxville, and also the current listing of quality-impaired waters within the city limits. Some watersheds are located entirely within the City of Knoxville; other watersheds extend outside the city limits and are thus shared jointly by the city and county governments. Watershed boundaries, names and locations are shown online at the Water Quality Forum website -- http://www.waterqualityforum.org/.

Regional planning is currently conducted on a limited basis when funds are available. A few regional detention basins have been constructed at locations with known drainage problems and very inexpensive land; however, this combination of factors does not occur very often. The ability of the municipal government to change the city landscape, or to modify even small drainage systems, is very limited. Major reasons include:

- Existing property and land uses, once approved and constructed, are legally grandfathered and protected, unless the city or state government can show overwhelming evidence that changes are necessary to protect the general welfare.
- The existing stormwater drainage infrastructure is very expensive to replace or modify, particularly bridges and highway culverts. Maintaining transportation routes is a basic function of any government, which severely limits economically feasible work in and near streets or highways.
- Land along the natural creeks and streams includes many older parts of the city, with drainage pipes 50 to 75 years old. Older portions of any stormwater drainage system typically have low conveyance due to poor maintenance or and were not designed according to modern standards.
- Limitations and constrictions that are caused by older, undersized or incorrectly installed drainage pipes will affect system performance for a considerable distance upstream.

Regional planning, when fully implemented in the future, will typically consist of HEC-HMS and HEC-RAS models (to support water quantity and flooding computations) along with a mixture of stormwater quality methods and models to satisfy TDEC pollution reduction goals. The potential impacts of stormwater regional planning on typical site development projects are:

- Durable materials with an expected 100-year life for drainage pipe, culvert or channel are required for stormwater conveyance systems that handle offsite drainage. Reinforced concrete pipe (RCP) is specified for pipes and culverts within the public right-of-way.
- A larger size of drainage pipe, culvert or channel may be requested by the Stormwater Engineering Division for stormwater conveyance systems that handle offsite drainage. This may occur even if upstream or downstream conveyances have smaller pipe sizes.
- Floodplains and stream buffers may be more uniformly managed to ensure adequate conveyance capacity.
- Stormwater treatment measures may be categorized into effective and ineffective BMPs based on Knoxville conditions, types of pollution, local stream sampling/testing, and water quality results.

Table 8-1
List of Watersheds Within the City of Knoxville

Watershed Name	City Watershed ID #	USGS Hydrologic Code (with 0601 prefix)	The combined 1998/2000/2002 listings of 303(d) impaired streams for TMDLs (Total Maximum Daily Loads)									
			-----	Flow Alterations	Habitat Alterations	Low Dissolved Oxygen	Metals	Nutrients	Organic Enrichment	Pathogens	Priority Organics	Siltation
Ft. Loudoun Lake (Tennessee River)	00		PCBs								✓	
First Creek	01		**TMDL-1**		✓			✓		✓		✓
Second Creek	02		**TMDL-1**		✓		✓	✓		✓		✓
Third Creek	03		**TMDL-1**		✓			✓		✓		✓
Fourth Creek	04		**TMDL-2**		✓					✓		
Goose Creek	05		**TMDL-1**		✓					✓	✓	✓
Baker Creek	06		**TMDL-2**		✓					✓		
Williams Creek	07	0201	**TMDL-2**		✓					✓		
Knob Creek	08											
Toll Creek	09											
Ten Mile Creek	10											
Whites Creek	11		**(TMDL-1)**		✓			✓		✓		✓
Turkey Creek	12							✓		✓		✓
East Fork	13		**(TMDL-1)**		✓			✓		✓		✓
Spring Creek	15											
DeArmond Spring Br.	16											
Sinking Creek	18									✓		
French Broad River	30	0107		✓		✓		✓	✓			
Holston River	50				✓							✓
Swanpond Creek	51				✓							✓
Inman Branch	52	0104										
Love Creek	53				✓							✓
Woods Creek	54											
<Clinch River>	70											
Beaver Creek	71	0207			✓					✓		✓
Grassy Creek	77											✓
Knob Fork	79				✓							✓
Little River	90					✓		✓	✓		✓	✓
Stock Creek	91	0201			✓	✓		✓	✓	✓	✓	✓
McClure Creek	99											

8.6 Total Maximum Daily Load (TMDL)

TDEC, in accordance with mandates from the U.S. Environmental Protection Agency, has made comprehensive lists of polluted streams and rivers within the state of Tennessee. The 303(d) list is compiled using the Hydrologic Unit Code (HUC), an eight-digit number that indicates the watershed as mapped by the United States Geological Survey. The 303(d) list is updated every two years by each state, with requirements for the list to be publicly available and for the individual cities and counties to be very proactive in addressing the cited types of pollution. See the TDEC website for the current 303(d) list; streams may be added to the list or even removed if the pollution reduction goals have been met.

TDEC has authorized pollution reduction goals for various streams across the state of Tennessee, based on modeling the specific pollutants to determine a total maximum daily load (TMDL). Water quality models are developed and then calibrated using existing data such as average flow discharge or water quality. The initial wave of TMDL studies modeled for the Knoxville creeks and streams in February 2003 are for fecal coliform pollution (pathogens) and are shown in Table 8-1. Additional pollutants (sediment, heavy metals, nutrients) will be modeled in future years. Since the City of Knoxville must meet TMDL goals and targets for each listed creek and stream, additional measures for pollution reduction may be required above and beyond the first flush criteria.

8.7 Preservation of Natural Creeks and Streams

Preservation of Knoxville's natural waterways has been encouraged and promoted by the city government and by local environmental groups. The City of Knoxville has a creek cleanup crew that not only handles trash and debris, but also does minor inspections, maintenance and minor restoration along creeks. IJAMS nature center (http://www.ijams.org) and Keep Knoxville Beautiful (http://www.kornet.org/keepknox) have been very effective for several years in raising citizen awareness, providing educational programs for children, organizing creek cleanup days, and labeling storm drain inlets. Other environmental awareness groups have also been very active in the Knoxville area. The Adopt-A-Stream program and other watershed initiatives gives many citizens a chance to enjoy local streams while serving the community's interests also.

A system of parks and greenways (generally following the creeks) has been implemented across Knoxville and continues to grow year by year. Portions of the system connect to greenways outside the city limits that are maintained by Knox County. As development and redevelopment occurs along natural creeks, property owners are required to cooperate with greenway plans and routes established by MPC. Typically this is done through greenway and conservation easements, along with "green development" along streams and creeks wherever possible.

Stream buffer zones have been established for blue-line streams. All new development and redevelopment adjacent to a blue-line stream must have a restricted-use buffer zone for construction. In addition, a separate no-fill line is established on streams which have been studied by FEMA. The no-fill line is halfway between the 100-year floodway and the 100-year floodplain fringe. See Section 22.5-21 of the Knoxville Stormwater and Street Ordinance for detailed information.

8.8 Sinkholes

The Knoxville area contains a lot of sinkholes due to the presence of karst geological formations. The general topography of the region is a series of hills and ridges that are aligned in a direction from southwest to northeast. Limestone rock groups are folded in layers at various angles, so that outcroppings are hard to predict. Natural depressions usually indicate the presence of sinkholes. In instances where the Stormwater Engineering Division suspects that a sinkhole is involved, a TDEC expert can be summoned to make a final determination. An Aquatic Resource Alteration Permit (ARAP) is required if a property development includes filling within the limits of a sinkhole, due to the interest TDEC places in protecting groundwater resources.

The presence of a sinkhole on a property can affect the amount or types of project development that may be allowed. Policy 12 (Sinkhole Development) in Appendix C contains a definition of what a sinkhole is, typical restrictions, necessary volume computations, and locations of notable sinkholes with documented drainage problems. Sinkholes have occasionally been observed to stop draining properly; in some cases, it appears to have been caused by construction work nearby. In other instances, there is no known cause for the failure to drain. Therefore, every sinkhole is analyzed from the position that it will become plugged someday or simply may not drain adequately during design storm conditions.

A sinkhole must not be considered as a stormwater infiltration measure, as it does not have a designed flow rate and may even connect directly to the groundwater table. See ST-03 in the Knoxville BMP Manual for a description of stormwater retention and infiltration systems. It is not unusual for an existing neighborhood to contain several sinkholes, as they have traditionally been considered reliable drainage outlets in decades past. The total volume of stormwater runoff draining into a sinkhole must not be increased. Extended detention basins shall be designed to reduce postdeveloped stormwater runoff volumes to the level of predeveloped volumes. Any chemicals or pollutants in stormwater runoff could potentially change pH values and cause further dissolution of limestone formations.

Policy 12 also requires that a sinkhole easement, and in some cases an associated sinkhole access easement, will be dedicated around the sinkhole for the purposes of allowing inspection and potentially maintenance to correct drainage problems.