State of North Carolina

North Carolina Department of
Environment and Natural Resources
Division of Water Quality

Stormwater
Management

Site Planning

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The mention of trade names, products or companies does not constitute an endorsement. This manual is intended for periodic update. Sections may be changed as practices for stormwater management evolve.

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Preface

The North Carolina Division of Water Quality has prepared this guidance document to promote and encourage the use of preventive, source reduction and control practices throughout the site planning process in the design of stormwater runoff management sytems. By doing so, individuals and local governments who are involved in the development of land in North Carolina will support statewide efforts to maintain and improve surface water quality by reducing non-point source pollutants and sediments in the stormwater runoff from urbanizing areas.

The intent of this document is to provide non-technical methods of considering the sources and effects of stormwater runoff as early in the site planning process as possible and to consider stormwater as a part of the site plan through all steps of the development process. When allowances for stormwater are made early in the site planning process, they can be integrated more thoroughly and thoughtfully into the design.

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Section One

Introduction

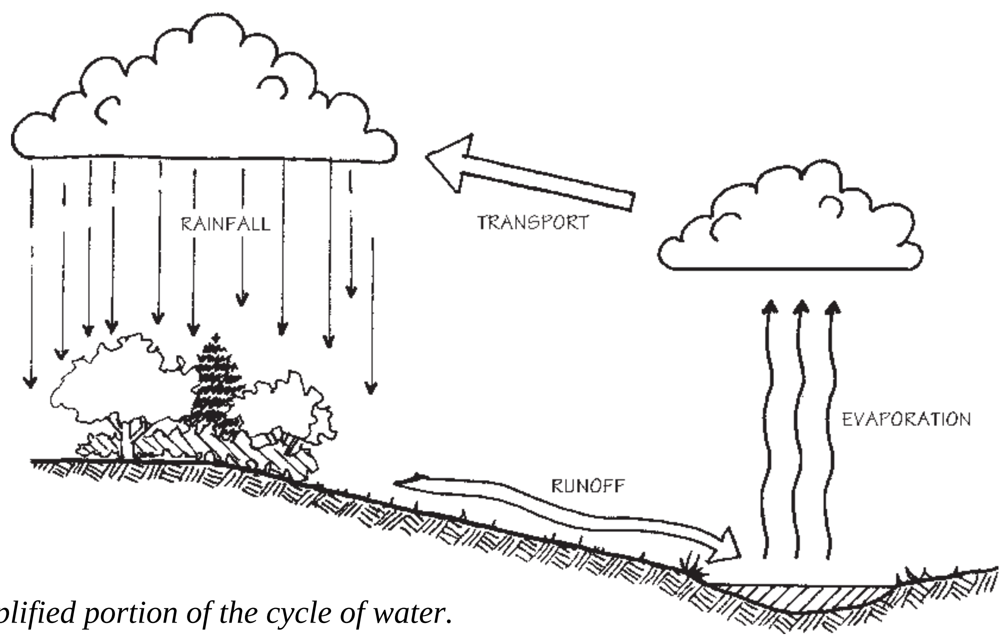
Site Planning

Site planning is the intentional thought given to the location and siting of human uses onto the land before they are built. The process of *site planning* has been practiced since the earliest times when man studied the landscape for the best location for an agricultural field or primitive hut. The decision was based upon information gathered through observation and through the experience gained from previous successes or failures. We continue today to face the challenge of siting our uses of land in the most beneficial manner which does not destroy the balance of natural resources or conflict with existing land uses.

Among the most important of natural resources which we must protect is our surface water. Surface water occurs in the form of rivers, streams, lakes, ponds, bays, sounds, and wetlands. The use of our surface waters can be impaired by pollutants and sediments carried to them by stormwater runoff.

Stormwater Runoff

Stormwater runoff is a naturally occurring part of the continuous cycle of water. When rainfall occurs on undeveloped land, the natural vegetation covering the soil surface intercepts the individual drops and allows the rain water to be gently returned to surface water and groundwater.



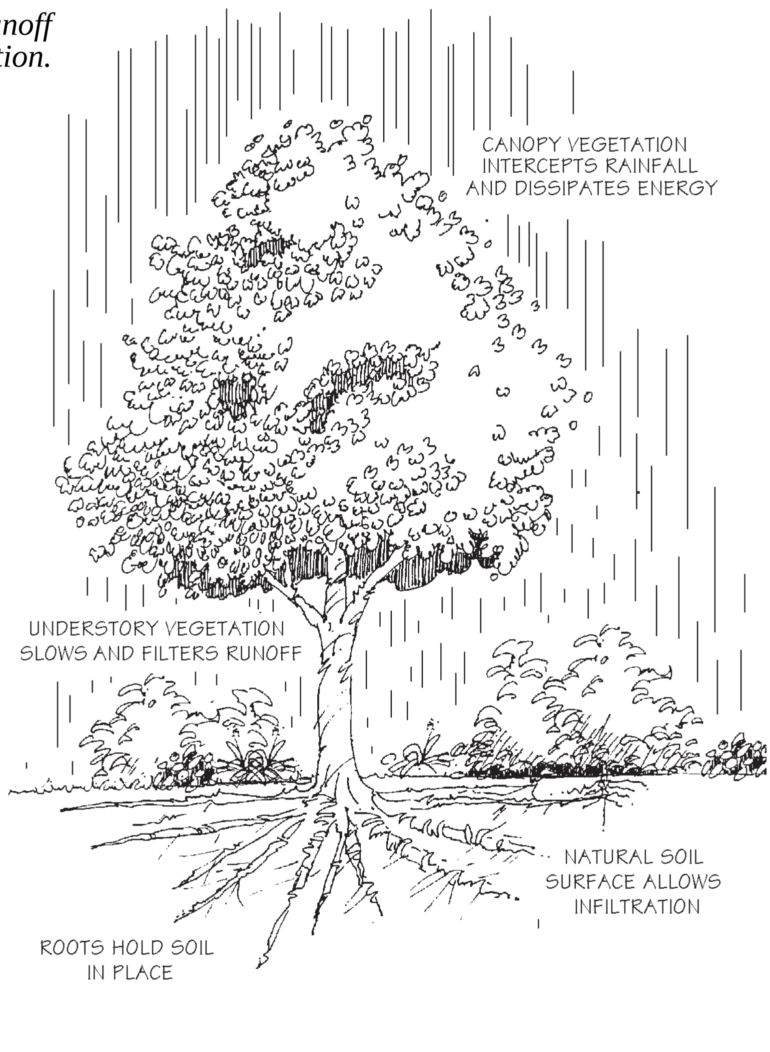
A simplified portion of the cycle of water.

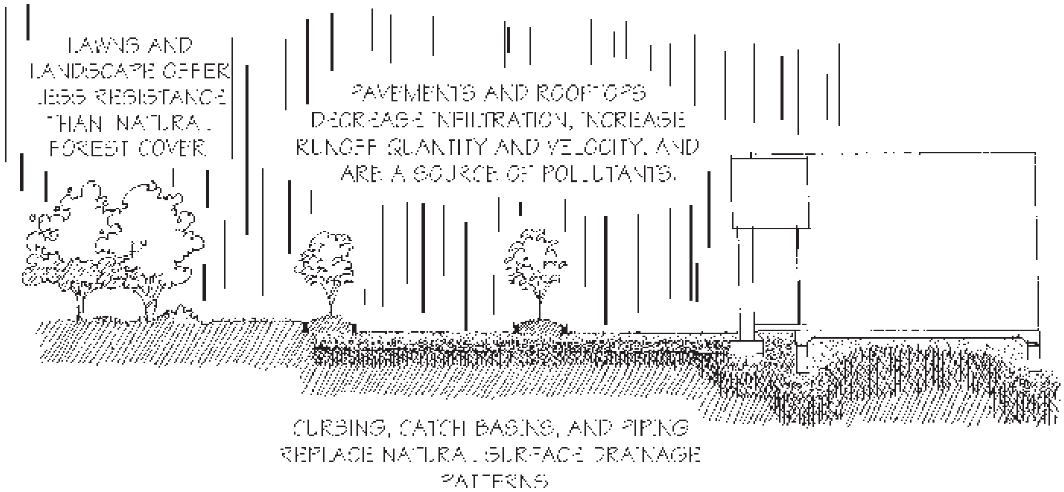
The components of natural vegetation play an important role in stormwater runoff management. Tree canopies break the fall of raindrops, diminishing their impact on the surface below. Dense understory growth and groundcovers impede rapid collection and runoff. Naturally uneven surfaces help to reduce the velocity of stormwater runoff and minimize erosion. Minor depressions allow the waters to be collected and released slowly back into the cycle by infiltration and evaporation.

As the water flows over the land, it dissolves and carries with it minerals from soil and rock and nutrients from organic materials. These materials are re-absorbed by the porous soil and vegetation. By the time the runoff reaches open water under these natural conditions, it is typically clear and and relatively free of an abundance of suspended particles or dissolved substances.

When the natural vegetation and topography of the land

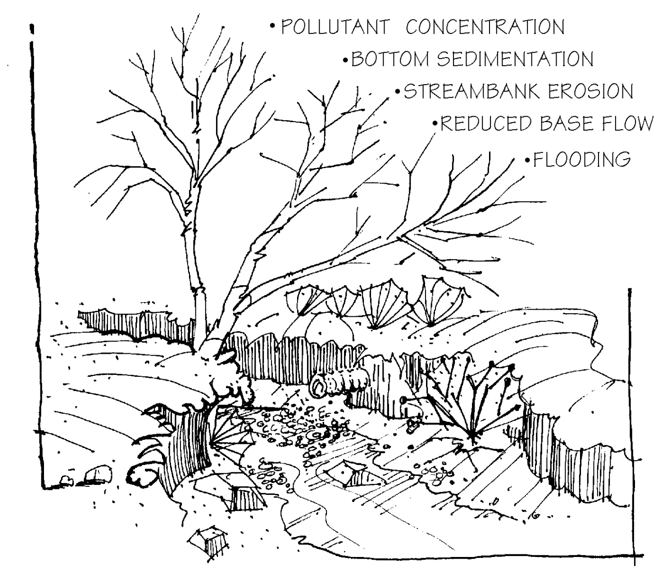
Natural vegetation slows runoff and allows infiltration.



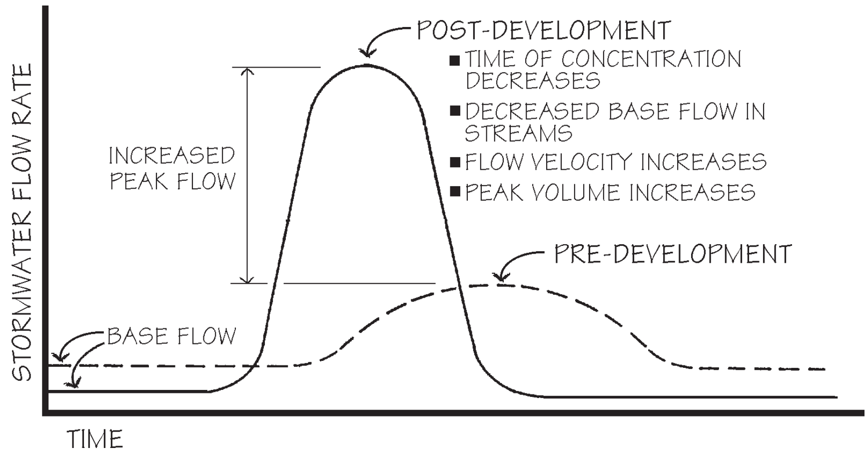


Development of land increases runoff and prevents infiltration.

are changed by development, the contours are smoothed and the landscape is comprised of hardened surfaces (rooftops, parking areas, etc.) and landscape plantings. These changes offer less resistance to the flow of stormwater runoff than the natural topography and vegetation. The resulting runoff travels at a higher velocity with increased erosive potential and has the ability to carry suspended and dissolved materials over much greater distances. The collected materials are ultimately deposited into surface waters as pollution. In addition, this rapid runoff prevents rainfall from infiltrating into the ground. This infiltration is necessary to recharge the groundwater table and reduce stream base flows.



Uncontrolled runoff can degrade the quality of surface waters.



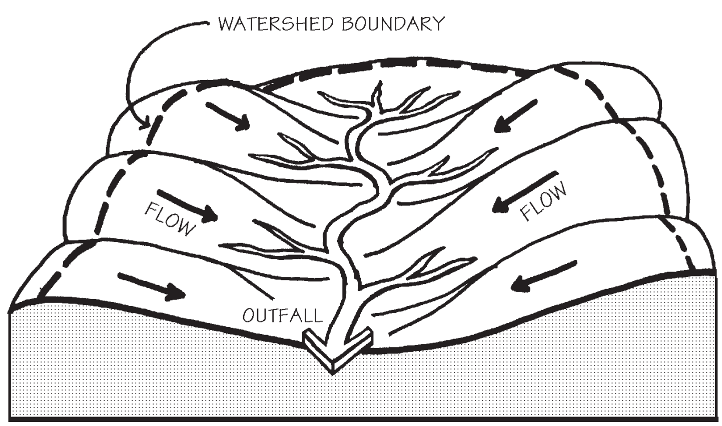
Development causes changes to stream flow.

Changes to Flow

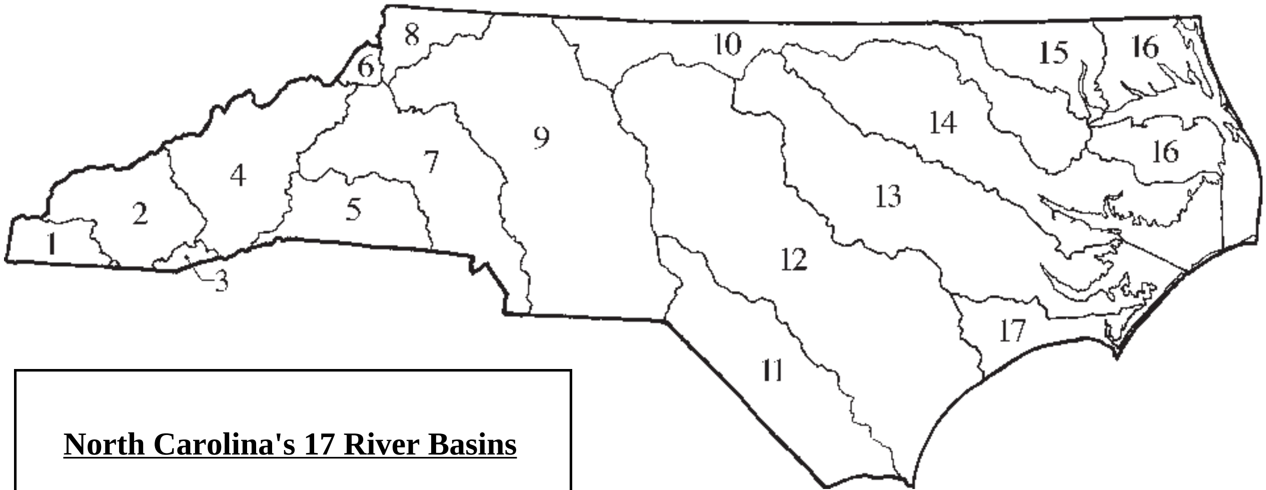
The time that it takes for runoff to collect at points of outfall is known as *time of concentration.* When the land is smoothed by development this time of concentration is greatly reduced. Volumes of runoff entering surface waters at one time are increased since less is allowed to percolate through porous surfaces. These increases in volume, over time, can result in an accumulation of pollutants or sediments that can seriously degrade the water quality of receiving surface waters. When this occurs, their usefulness and value for recreation, drinking water, fish production, aesthetics, habitat quality, and a wide variety of other uses which society depends upon for health and livelihood is greatly reduced.

Watershed

An understanding of stormwater management begins with the concept of a *watershed, drainage basin,* or *drainage area*. These terms are similar in definition and are often used to describe the same thing. A watershed is comprised of the total land area contributing runoff to a given outfall location. A large area of land such as North America has numerous large watersheds (*river basins*) which eventually flow into the ocean in the form of rivers. All of the rainfall (or other precipitation) which becomes runoff within the river basin flows downhill until it reaches sea level.



A typical river basin watershed



<u>**North Carolina's 17 River Basins**</u>

1	**Hiwassee River**
2	**Little Tennessee River**
3	**Savannah River**
4	**French Broad River**
5	**Broad River**
6	**Watauga River**
7	**Catawba River**
8	**New River**
9	**Yadkin-Pee Dee Rivers**
10	**Roanoke River**
11	**Lumber River**
12	**Cape Fear River**
13	**Neuse River**
14	**Tar-Pamlico Rivers**
15	**Chowan River**
16	**Pasquotank River**
17	**White Oak River**

The State of North Carolina has 17 major river basins which collect all of the stormwater runoff generated by the land area of the State. The river basins form the basis for monitoring and managing the state's water quality. Each major river basin can be divided into increasingly smaller sub-basins (or drainage areas) as the topography is followed upstream. There is almost no limit to the minimum size of a drainage basin, even a relatively small site, such as a single family lot, may contain more than one drainage basin.

All land uses within a watershed will contribute runoff to the same outfall point. Controlling the amount of pollutant and sediment which accumulates at the outfall of the watershed is most effectively accomplished by preventing these pollutants from entering the runoff in upstream areas. Regulatory controls which are in place at the Federal, State, and local level take into consideration the relationship of the sources of stormwater runoff within upstream areas of a watershed as well as areas which are likely to be impacted by this runoff. The control of surface water quality by managing the source of runoff within a watershed is known as a *watershed-based approach.*

North Carolina Water Quality Protection Strategies

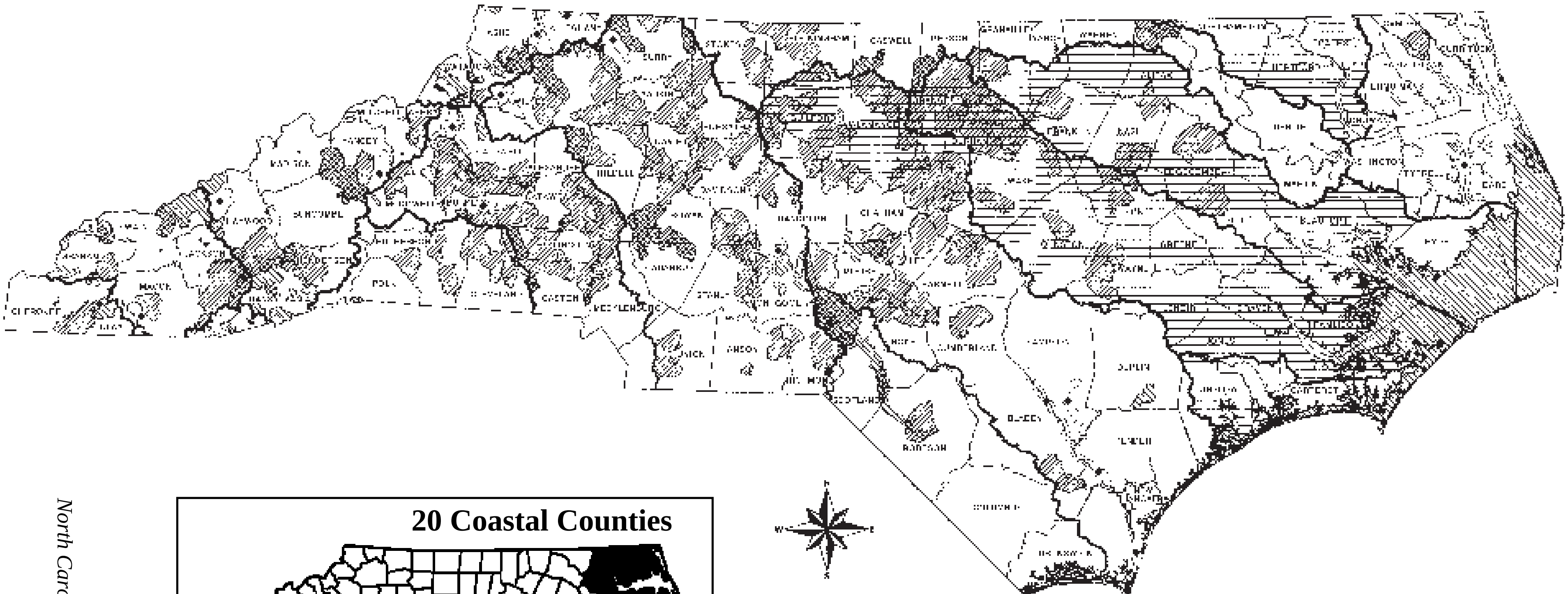
20 Coastal Counties
High Quality Waters
Outstanding Resource Waters
Water Supply Watersheds
Nutrient Sensitive Waters and
NPDES Programs
(including MS-4's)

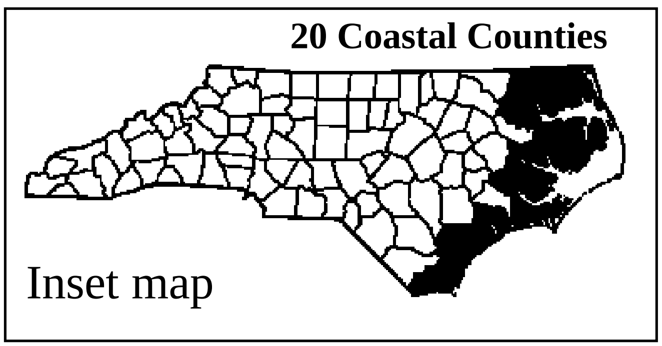
The State of North Carolina has taken a watershed based approach to monitoring and managing its water quality by preparing Basinwide Management Plans for each of the 17 major river basins within the state. The overall quality of surface waters within each of the major river basins is protected through a variety of strategies including surface water classifications, regulations for point source discharges (NPDES program) and through Best Management Practices for non-point sources such as forestry, agriculture and developing areas. In North Carolina, a number of requirements are currently in place for urban stormwater management. These requirements result in stormwater management measures for new development activities in certain sensitive areas including Water Supply Watersheds, Nutrient Sensitive Waters, Outstanding Resource Waters, High Quality Waters, and Coastal Waters. These designations are defined in North Carolina Administrative Code, Section 15A NCAC 2B .0100, Procedures for Assignment of Water Quality Standards.

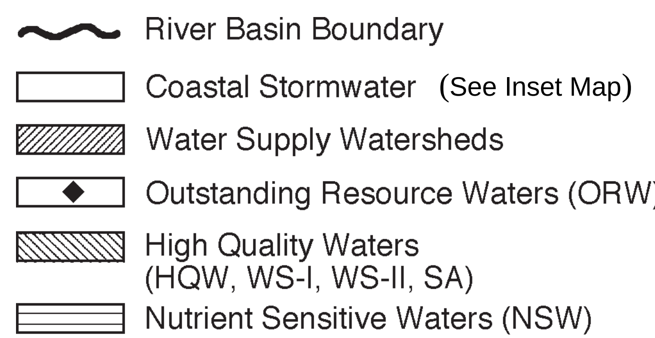
In addition to State and Federal programs, municipalities may have land use regulations such as zoning ordinances and stormwater runoff management regulations. Statewide, most land disturbing activities are required to implement sediment and erosion control measures during construction in order to prevent sedimentation of our surface waters. The state sedimentation and erosion control program is administered by the Land Quality Section of NCDENR.

The approach which the state has taken can be considered as site planning over a very wide area. For an individual parcel, a watershed-based approach will follow the lead established by the State of North Carolina in its Basinwide Management plans. The methods established by the Basinwide Plans are applied to smaller and smaller drainage areas within each river basin until the level of site planning for use of an individual parcel is reached. The watershed based approach to site planning for stormwater runoff management can be applied to the smallest discernible basin within a given project and extended to all portions of the site. This occurs best when regulations and economics work together to support the effort.

The following map reflects the water quality protection strategies for North Carolina.







North Carolina Water Quality Protection Strategies

Adapted from maps prepared by NC Center for Geographic Information & Analysis, August 1996
This map is for general information only. For detailed map information contact CGIA at (919) 733-2090

There are many types of land use and development which contribute sediments, nutrients and other pollutants to surface waters through non-point source runoff. The individual effect of each lot, or parcel, or land use may seem minor, however, their combined influence can be significant. Additionally, many existing land uses can improve the quality of the runoff they generate through means such as modification of operation and maintenance methods, minor changes to site design, public education and awareness, and retrofitting aging stormwater runoff controls with newer methods which result in higher quality discharges.

The management of stormwater runoff in a manner which maintains an acceptable level of surface water quality requires participation at all levels and involves both regulatory controls and efforts put forth by individual property owners and developers. Regulatory methods of management rely on enforcement of permits and standards for controlling the quality and quantity of runoff generated within the area of jurisdiction. Regulatory controls implemented at Federal, State, and local levels typically provide a means of controlling specific sources of pollution. Individual property owners, at a minimum are required to comply with regulations pertaining to their particular land use. They also have the opportunity to provide a higher level of participation in controlling the quality of runoff before it leaves their property. Ideally, the runoff generated by a developed property would be of a quality comparable to that of undeveloped land. This can be done in a cost effective manner through good design and implementation, and subsequently through appropriate operation and maintenance.

Through good design and implementation the quality of runoff from a developed land can be comparable to that of undeveloped land.

Stormwater runoff from urban and developing areas is becoming an increasingly important area of concern. Regulations for control of these pollution sources has expanded over the last few years and it is expected that these will continue to expand due to the increasing growth in North Carolina. As a result, this manual attempts to promote meeting these requirements through sound site planning procedures that utilize prevention, source reduction and, where necessary, well planned control measures.

Section Two

A Watershed-Based Approach to Site Planning

Watershed-based Approach

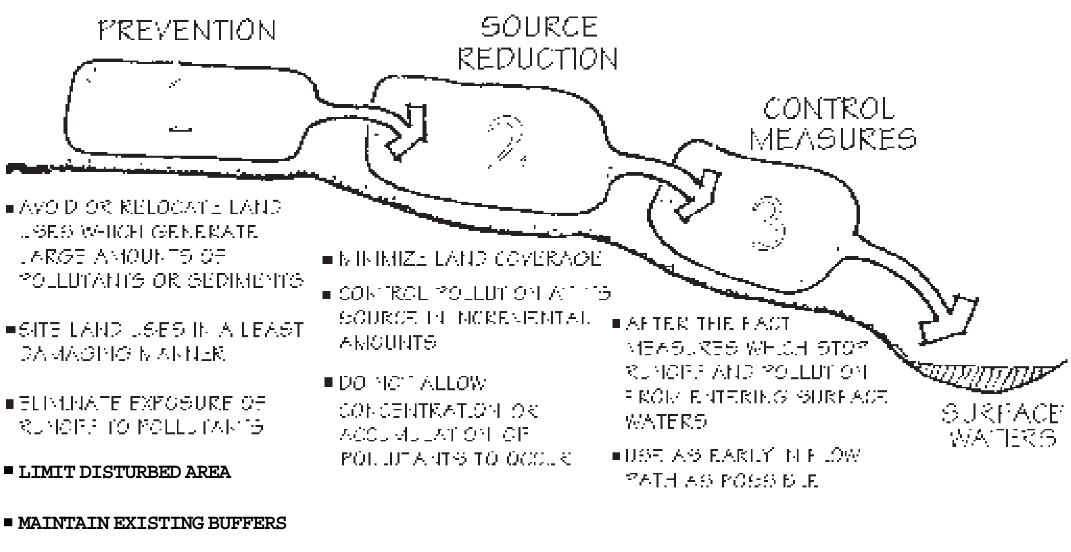
A watershed-based approach to stormwater management is the most effective means of managing runoff quality for every site, regardless of size. Site planning for an individual parcel using an integrated system approach involves the creation of a site specific management plan with a combination of *preventive measures*, *source reduction practices*, and *control measures* to comply with the requirements of the law.

Integrated Systems

Preventive measures reduce the impacts of stormwater runoff on surface waters through changes in design, operation or management. These changes are made in a manner which reduces or eliminates the pollutants being generated or made available to enter the surface drainage system. Preventive measures do not usually involve the construction of special devices. If implemented properly they should require little additional expense to the normal costs of design, construction or management and can in many instances reduce costs over the life of a project.

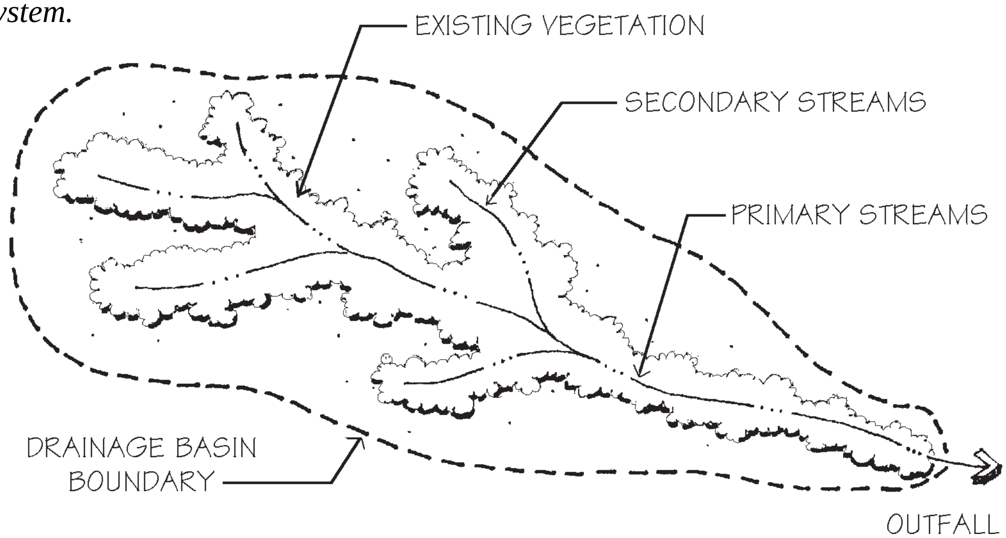
Source reduction practices reduce the pollutants generated at a given source. Minimizing land coverage and impervious surface, for example, will encourage infiltration of runoff, reduce its quantity and improve its quality.

The final method of ensuring runoff quality is through the use of *control measures*. Control measures are devices or facilities that are constructed or installed to capture stormwater and reduce or remove pollutants before they are allowed to enter surface waters.

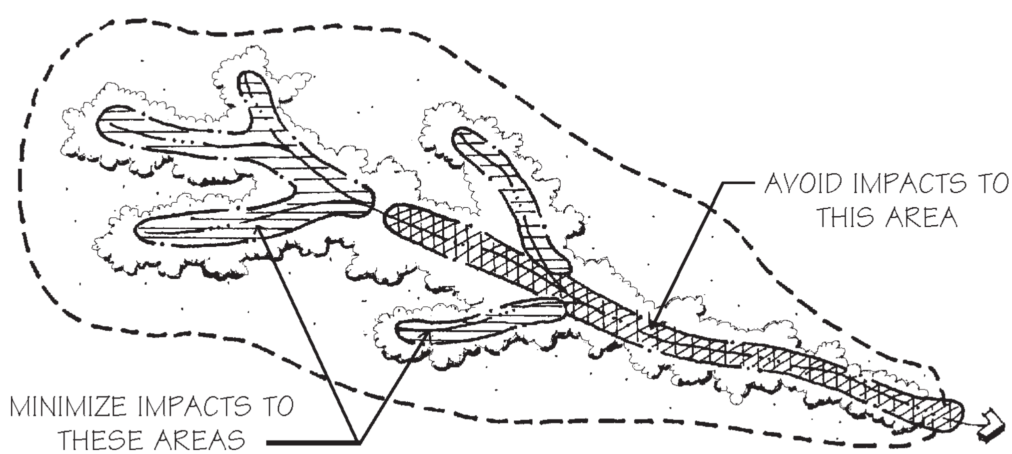


All components of a stormwater management system must be designed to work together. A well designed integrated stormwater management system will prevent pollution from being generated at its source. This is accomplished by minimizing exposure of pollutants to stormwater and removing pollutants from runoff as close to the source of exposure as possible. This will prevent the pollutants from being transported into surface waters. A well designed system should also be easy to maintain. This is best accomplished by following a sound site planning and design process which considers stormwater runoff from the very beginning and incorporates the integrated system of components throughout the entire site. Each site has a unique set of characteristics and requirements; therefore, each site should have a specifically designed stormwater system to optimize available resources and to meet stormwater quality objectives.

Every site has an existing natural drainage system.



This natural drainage system can be incorporated into a stormwater management system if it is not destroyed.

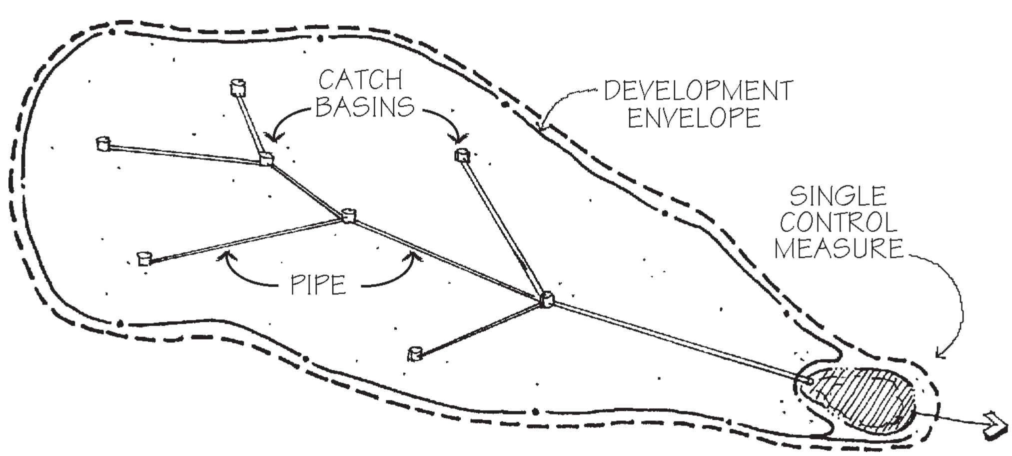


Traditional Approach

Traditonally, the focus has been on water quantity, not water quality. Now, water quality is becoming more and more of an issue, that must be addressed.

A traditional approach to stormwater management has been to drain runoff into a series of inlets, catch basins, pipes, culverts or drainage channels as quickly as possible in order to prevent temporary ponding of runoff on a developed site. Structures are designed and sized to carry a certain quantity; however, they do not attempt to minimize the quantity of stormwater runoff before it is generated. When the design of these structures does little to reduce the peak rate of discharge or to prevent pollution from entering stormwater, areas located downstream of the development are subjected to increased storm flows and impacts to surface water quality because the frequency and severity of downstream flooding increases and the quality of receiving waters decreases. Downstream channels often require expensive modifications to transport the increased flows and to control streambank erosion.

An improvement to the traditional methods used in many areas was the attempt to return runoff generated by a developed watershed to pre-development hydrologic conditions. The quantity of runoff from a site would not exceed the quantity which occurred before development. This process relied heavily on the use of large control measures employed after the runoff had already been generated. Detention and retention structures were the first to be employed to reduce runoff quantity. More recently, infiltration devices have been used to keep some runoff on the site. While primarily intended for control of quantity, the use of these control measures can have the additional benefit of improving runoff quality. For example, a wet pond used for control of flooding can also be effective at pollutant removal. Locally, the development regulations of many municipalities in North Carolina focus primarily on the control of runoff quantity; benefits to runoff quality have been secondary to issues such as flood control.

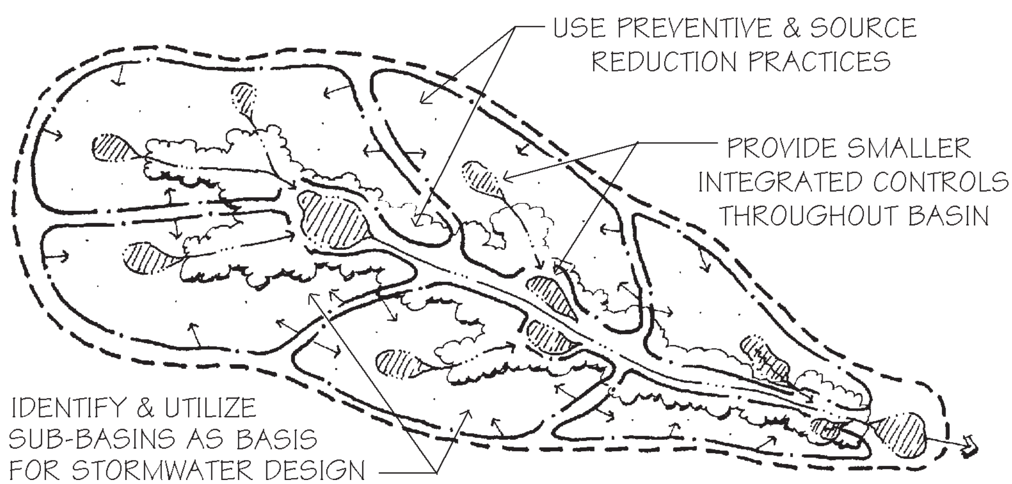


A traditional piped stormwater system replaces the natural drainage systems found on a site but does not provide equivalent water quality control.

A more comprehensive approach to site planning for stormwater management incorporates the use of natural drainage systems and an integrated system of preventive and control practices as an alternative to the use of traditional piped systems. A stormwater system designed in this manner should function as though it were a part of the natural surface drainage system.

In order to employ this type of approach during the site planning process, the entire site and its intended development must be carefully considered throughout the process. This involves a thorough understanding of the physical characteristics of the site and the preparation of a site plan which responds to them. Certain ways of developing land can minimize the impact on the environment. For example, fitting the development to the site to minimize land disturbances will greatly reduce erosion and sediment in nearby water bodies during construction and throughout the life of the project.

A site should be divided into sub-drainage areas in order to efficiently and cost effectively control and treat stormwater runoff as close to its source as possible. Use of a hierarchy of basins to capture and control runoff in small increments before leaving the site and employment of a variety of Best Management Practices to capture sediments, toxins, grease/oils and nutrients will allow pollutant sources to be targeted and controlled in smaller quantities.



A watershed-based site plan employs the use of natural drainage systems, smaller sub-basins, and an integrated system of prevention, source reduction, and best management practices.

The most effective methods of stormwater runoff management incorporate a simulation of the functions which occur under natural conditions. Methods of this type serve to slow runoff velocity which reduces erosive potential, allows particulate and suspended materials to settle out, and allows porous areas to absorb surface runoff into the groundwater. As stormwater is detained and filtered through vegetated areas or other types of filters, undesirable substances dissolved in the water, such as nutrients or toxins, can be assimilated before reaching surface waters.

An effective stormwater management system should consider the present and future setting and conditions found on a particular site. Ideally, if every site were bounded by the limits of a defined drainage area, the only consideration would be for stormwater generated on-site. This setting is typically not the case. Physical factors which should be considered for stormwater runoff planning include not only those within the property line, but also those located upstream, downstream, above and below the site.

Runoff contributed to the development site from upstream areas influence both quantity and quality considerations. In certain instances, this runoff can add value to a site by providing an opportunity to create an amenity. In other instances, the runoff generated by upstream areas may pose a problem if runoff quality is very low or if quantities are very high. Additionally, upstream areas should be carefully reviewed during the design process to anticipate future problems which might occur as growth continues such as increases in storm flows.

Areas located downstream of a site are at risk of flooding if there is inadequate downstream flow. Excessive runoff generated on-site, low times of concentration, or the addition of new runoff to an existing system can cause this situation. Portions of a site which are flood prone prior to development, are likely to be subject to flooding after development.

The physiogeographic context of a site will have a great deal of influence on the overall design of a stormwater management system. Certain parts of the state have soil types and groundwater depths which will allow large amounts of stormwater to be infiltrated, thereby reducing the amount of runoff being generated. Many other areas will have shallow groundwater or soils which have a high clay content, confining layer, or shallow bedrock which will limit the amount of stormwater which can be held on-site. Topography also plays an important role in the selection of an effective management system since slope characteristics have a tremendous influence over surface flow. Areas with steeper slopes require methods which closely control velocity and have the capacity to manage shorter times of concentration and higher peak storm flow volumes than areas with flatter slopes. A steeper site should be divided into a greater number of smaller basins than a flatter site of the same size for most effective control of runoff velocities and quantities, and ultimately runoff quality.

Section Three

Site Planning Goals for Stormwater Management

Site Planning Goals

The most basic purpose of site planning is to prepare a plan for the development of a parcel of land which accomplishes the goals of the intended land use. These goals will typically include:

- *compliance with development laws and regulations*
- *cost effectiveness and profit*
- *compatibility with existing land uses*
- *aesthetics and image*
- *long term sustainability of the development.*

Stormwater Goals

When stormwater runoff management is considered as a part of the site planning process, the goals of the plan should be expanded to:

- *prevent pollutants from being generated*
- *reduce the effects of pollutants at their source*
- *maximize the effectiveness of control measures*
- *improve the quality of runoff entering surface waters.*

The use of an integrated system of pollution prevention, source reduction practices, and control measures will allow the development to accomplish the stormwater management goals. In doing so, the stormwater system must also accomplish the goals of the development.

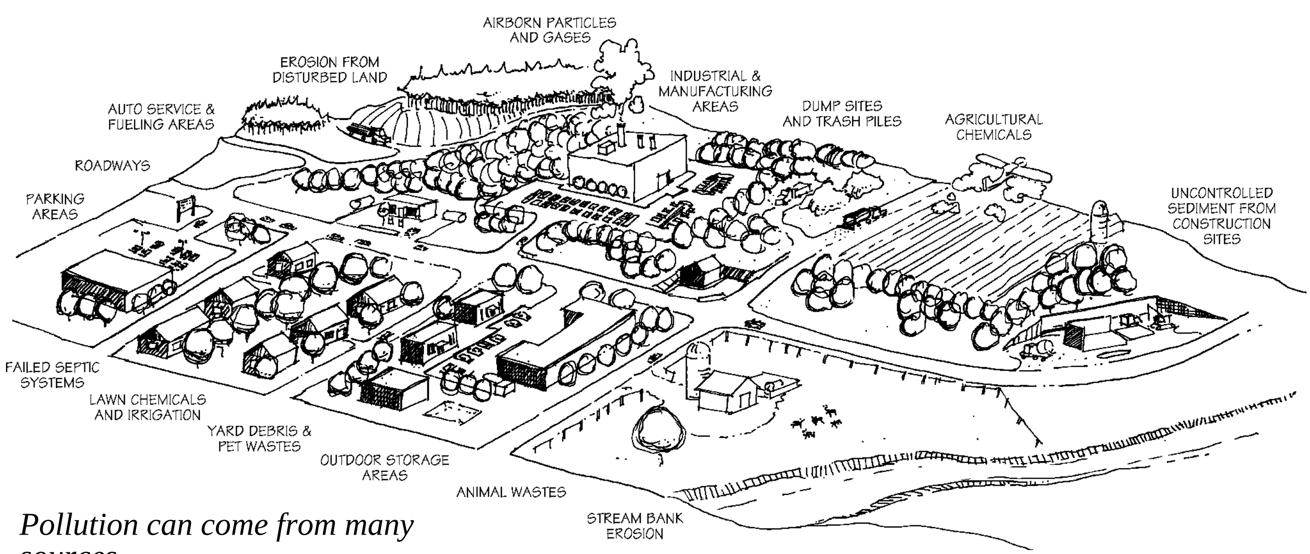
Preventive Measures

Preventive measures are the best assurance that pollutants will not be made available to runoff and will not be able to be carried to surface waters. Site planning for stormwater runoff management offers the first opportunity for preventive measures to be taken. During the site planning process, potential sources of pollutants can be identified and the land uses which are the cause of the pollutants can be sited in a manner which minimizes the exposure of the pollutants to rainfall and runoff. Stormwater runoff is a non-point source of pollution which arises from a wide variety of land uses within a watershed. Most urban runoff pollution problems come from human activities. Sources of contamination that contribute to urban runoff problems include:

Sources of Pollutant

• pollutants and dust deposited from the air,
• litter on streets and parking lots,
• decaying yard refuse, leaves and grass clippings,
• improperly handled garbage
• seepage from garbage cans, dumpsters, and refuse piles,
• stagnant water in depressions or catch basins,
• outdoor car and truck washing areas,
• fuel and chemical spillage storage and handling,
• fertilizers and pesticides,
• vehicle drippings - gasoline, oil, brake fluid, anti-freeze,
• service station areas and driveways,
• commercial and industrial areas,
• construction piles of dirt and debris,
• illicit dumping of contaminants into storm sewers,
• seepage from septic tanks and privies,
• inactive garbage dumps and poorly constructed landfills,
• poorly paved or unpaved streets,
• oil used for dust control on unpaved surfaces,
• animal droppings,
• snow and ice control chemicals used on roads.

The land uses which are a potential sources of pollution should be identified during the site planning process and sited in a manner which prevents the pollutant from being generated, limits the contact of pollutants with runoff or rainfall, or allows the runoff from these areas to be captured and treated before it reaches surface waters.



Pollution can come from many sources.

Urban Prevention Measures

- *Reduce impervious surface*
- *Increase open space*
- *Maintain buffers*
- *Utilize existing drainage patterns*

Many non-point sources of pollution in urban runoff are associated with impervious surfaces. Limiting the density of development and reducing the impervious area allows a greater portion of a site to remain in a natural state. Since less of the site is developed, there will be fewer sources of pollutant to contribute to the flow. An increased amount of open space will allow for a greater amount of runoff to be infiltrated. One means of limiting development density is by clustering land uses within a development. Clustering concentrates land uses into a smaller portion of the site and leaves open space between clusters.

The incorporation of existing drainage patterns and natural vegetation into a site plan will prevent pollution by allowing the natural features of the land to help control runoff and filter pollutants. Buffer strips of vegetation which are left along waterways will help to prevent pollution by capturing pollutants and sediments in runoff before they enter the open water.

Since preventive measures are not constructed devices and most require only a change in the manner in which activities are conducted, they are among the most effective and affordable of methods of improving the quality of runoff.

Source Reduction Practices

Source reduction practices minimize the pollutant load in runoff. These measures employ modifications of the design of a site which will reduce the amount of pollutants carried by runoff and prevent it from accumulating. This is accomplished in two ways, by reducing the amount of pollution at its source and by reducing the amount of runoff or its ability to carry the pollutants.

There will always be some amount of pollutant present in stormwater runoff. The goal of source reduction is to keep the amount of pollutant to a minimum so that fewer expensive control measures are required to remove it before it enters surface waters. Many of the preventive measures already mentioned could be considered as source reduction practices when they are incorporated into the site plan.

Components of a site plan which reduce the contact of runoff with pollutants include the diversion of stormwater away from a concentrated source of contaminants. Measures such as openings in curbs allow stormwater to be dispersed into open areas. If curb openings are provided at frequent intervals, the quantity of runoff which will accumulate at any one point will be reduced.

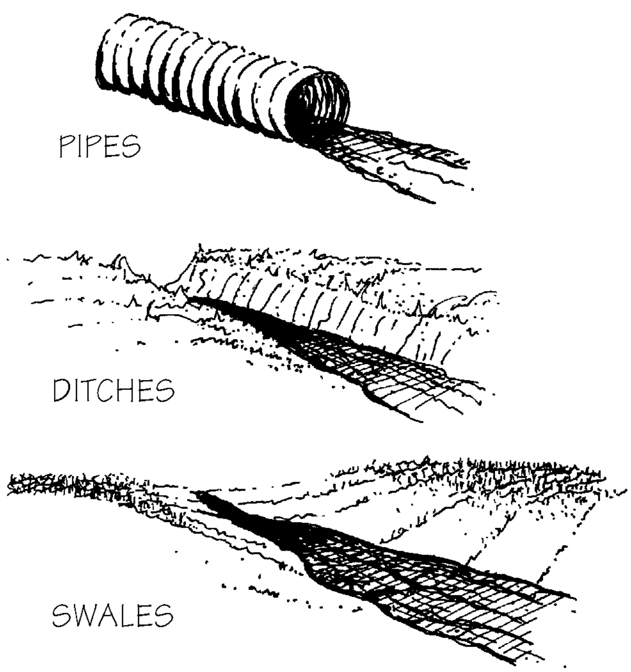
Control Measures

After every effort has been made to prevent and reduce the amount of pollutant in stormwater runoff, a series of control measures should be used to capture and treat runoff before it is released to surface waters. Control measures are referred to as Best Management Practices, or BMP.

Control measures are devices which are constructed on a site to capture, transport, store, filter, infiltrate, and treat runoff before it leaves the site. A control measure can be generally grouped into one of four categories depending on its function and design. Each category of control device is intended to perform the pollutant removal function of its counterpart found in a natural drainage system. Control measures have various levels of pollution removal efficiency/effectiveness. Specific design information and removal efficiency can be found in the 1995 DWQ document on Best Management Practices. The BMP document is available from the DWQ Central Office. See Appendix 2 for the address and phone number.

Conveyances

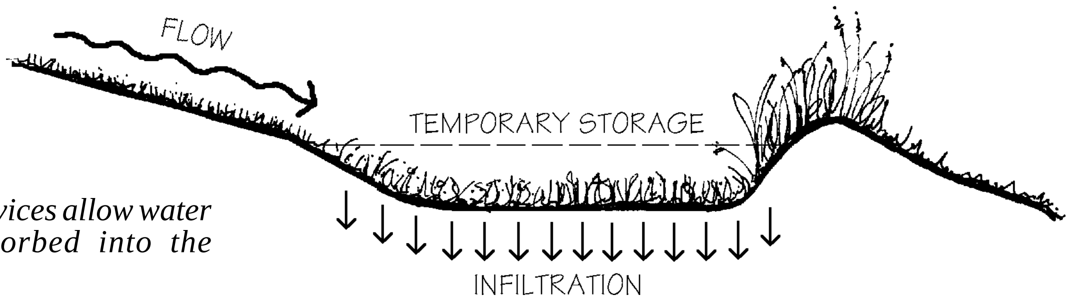
Conveyances are devices which capture and transport stormwater runoff. These devices serve a purpose similar to natural drainageways and stream channels. When runoff is transported by a conveyance designed for the purpose of pollutant removal, its velocity is slowed and vegetation within the conveyance traps pollutants and sediments.



Conveyances replace natural drainageways by carrying surface flow. Vegetated swales are used to slow runoff and remove pollutants that would not be removed by the smooth surfaces of pipes and lined ditches.

Infiltration devices

Infiltration devices provide an opportunity for runoff to be temporarily stored so that it has an opportunity to soak into the ground. Some of these devices are very large in size and are intended to handle large quantities of runoff collected from a broad area. Other infiltration devices are very compact in size and are well suited for use in more densely developed settings closer to the source of runoff. All infiltration devices will reduce the quantity of runoff which is released from a site as surface flow. These devices also provide control of runoff quality by absorbing and witholding pollutants and sediments. Infiltration devices serve a purpose comparable to forest soils in a natural drainage system.



Infiltration devices allow water to be re-absorbed into the ground.

Storage devices

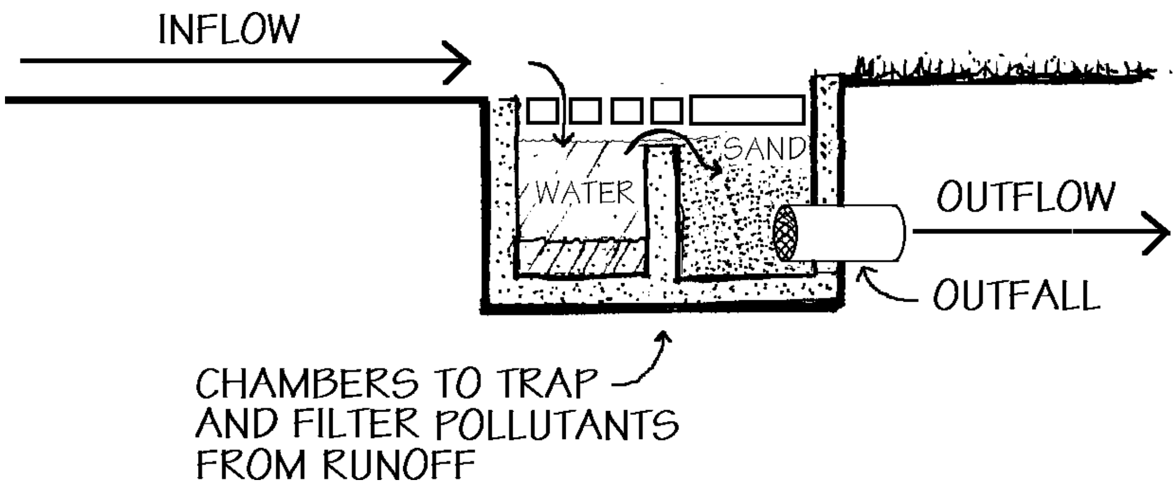
Storage devices are control measures which are designed to collect and hold runoff for a period of time which may range from a few hours to permanently. The basic design of storage devices resembles that of a pond. These devices usually consist of a storage basin which is formed behind an embankment, some means of controlling flow out of the basin, and in most instances a means of capturing and treating runoff as it enters the basin. Storage devices serve a purpose comparable to floodplains, landscape depressions, wetlands, and ponds which are found in a natural drainage system. These devices slow the rate at which runoff is released into surface waters and provide a means of pollutant and sediment removal through settling and biological activity.

Storage devices will hold back flow for a period of time to allow pollutants to settle.

Traps and filters

Traps and filters are control devices which serve a very specific purpose; to capture runoff and provide treatment which removes pollutants, sediments, and other materials. These devices rely on mechanical means of filtering the runoff as it passes through. Most of the traps are very small in size and are designed to treat the runoff from a small drainage area. These devices are designed so that they can be cleaned out as necessary.

Filters can be of almost any size or shape depending upon the characteristics of the drainage area being served. The purpose of a filter is similar to that of a trap in that it removes sediment, pollutant, and debris as runoff passes through the device. Both traps and filters serve a purpose comparable to the natural vegetation and soil surface found in a natural drainage system.



Traps are in-line devices used to mechanically remove pollutants from runoff .

The use of a series of measures which complement and support one another throughout the site plan will maximize the effectiveness of each. When control measures are included as a part of an integrated system of preventive measures and source reduction practices they will help to achieve the stormwater runoff water quality goals of the development.

Section Four

Components of the Site Planning Process

When runoff management is considered to be a *part* of the design instead of an addition to it, a development will generate as little runoff as possible and will control the quality of that which is generated. The process of site planning for stormwater runoff management involves the following steps:

1. Site inventory and analysis
2. Program development and conceptual planning
3. Master planning
4. Construction documents and details
5. Implementation
6. Operation and maintenance

Overview of the Site Planning Process

Before site planning for a development can occur it will be necessary to determine the regulatory requirements which will apply to the site.

Before the process of designing a comprehensive, cost effective, and integrated stormwater management plan actually begins, it is necessary to determine the **regulatory stormwater requirements** which may apply to the site. The location of a site within a designated watershed, within a municipal jurisdiction, or near specially classified waters will dictate the manner in which stormwater is managed. Developments which occur in selected portions of the State are required to satisfy stormwater control requirements to protect and maintain water quality. These programs continue to expand as development and urbanization occur. Currently, the Division of Water Quality administers stormwater programs that include requirements for municipalities (MS-4's) which are required to have a stormwater NPDES permit, the 20 coastal counties, Oustanding Resource Waters, Water Supply Watersheds, High Quality Waters and Nutrient Sensitive Waters (as shown on the Water Quality Protection Strategies map on page 7). Local governments may also have specific stormwater management requirements including on-site retention, buffer or setback requirements, or impervious surface area limitations.

Site Inventory and Analysis

The site inventory and analysis provides a means of gathering and mapping information about the site and its surroundings and putting it into a form which can be used as a basis for the design.

Once the basic legal requirements are established, the physical characteristics of the site and its surroundings must be carefully reviewed and analyzed with the intended land use in mind. This step in the process is known as a *Site Inventory and Analysis*. The site inventory and analysis provides a means of gathering and mapping information about the site and its surroundings and putting it into a form which can be used as a basis for the design. Information which is gathered and interpreted as a part of this analysis and which will have a significant influence on stormwater runoff includes:

- project boundaries
- topography
- soil types
- vegetation patterns
- existing drainage features
- setbacks, buffers, easements
- rights-of-way
- surrounding land use
- special habitat restrictions
- preservation areas

Additional features which might influence the design include historical features, views, climatic factors, or noise. Since every site will have a unique set of characteristics which must be considered additional information can be added to the list, as necessary, for a particular site.

In order to make the gathered information useful for decision making, it is necessary to prepare a map or series of maps of the site onto which the information can be drawn or noted. The most basic map of this type is the *base map.* The base map is a plan view representation which depicts the site boundaries, the direction of north, and often a variety of other information, drawn to a scale (such as 1"=10') where one inch on the map represents an actual distance on the site. Information can then be mapped or noted at the scale of the base map and used to make decisions as the design process progresses. Each layer of information will have some importance to the design of a site plan and stormwater quality management system. How each of these layers is formed, and how it relates to the site planning process will be discussed in detail in later sections.

Program and Concept Plan

A primary goal of conceptual planning for stormwater management is to identify potential sources of pollutants and to prevent the runoff affected by these areas from directly entering surface waters.

In order to develop a parcel of land, it is necessary to know what elements are to be included as a part of the site plan and how they will generally be located on the land. These two steps in the design process are known as a *program for development* and a *conceptual site plan*. The program is a listing of the components of the intended development which identifies the land area requirements and relationships of each plan element.

The conceptual plan locates major plan components and their accessory uses, vehicular and pedestrian circulation patterns, required elements such as setbacks or buffers, and other plan elements onto the base map of the site. A primary goal of conceptual planning from the standpoint of stormwater management is to identify potential sources of pollutants and to prevent the runoff affected by these areas from directly entering surface waters. A conceptual plan should prevent or minimize the generation of unnecessary runoff.

Master Plan

The preparation of a detailed master plan provides an excellent opportunity to integrate stormwater runoff management measures throughout the plan as an intentional part of the design.

A *master plan* is a drawing of the site plan which shows more detailed design than the conceptual plan. The master plan situates plan elements at a common scale relative to one another and begins to show dimensional information, materials, surfaces, and quantities so that estimates and construction drawings can be prepared in order to implement the plan.

The preparation of a detailed master plan provides an excellent opportunity to integrate stormwater runoff management measures throughout the plan as an intentional part of the design. As facilities are situated on the master plan, thought should be given to their form and placement relative to the three dimensional characteristics of the site.

Using only the amount of impervious surface necessary to accomplish the goals of program requirements and considering the significance of each plan component as a potential source of pollution will reduce the quantity of pollutants being generated.

Locating facilities away from surface waters and the provision of ample buffers and vegetative filters will help to control the quality of surface runoff entering waterways. Integrating stormwater management into the open space and landscape elements of a plan in a multiple-use manner improves the efficiency of the use of land on a site. These areas provide an opportunity to reduce impervious surface, provide areas for absorption of surface runoff, and provide a means of slowing and filtering surface runoff near its source.

Stormwater control measures can be integrated into the development plan when they are considered as an important land use component of the master plan. In order to reduce velocity and pollutant load, stormwater runoff generated by the impervious portions of the site should be routed through natural conveyances which will provide longer travel times, provide some means of filtering or capturing sediments and pollutants, and if possible allow for absorption of a portion of the runoff.

Construction Documents

Construction documents (CD's) are the drawings and explanations which are used to construct the development. A set of construction documents consists generally of two parts - the construction drawings and the construction specifications.

The CD set of drawings depicts the manner in which the development will actually be built and specifies the materials and methods which are to be used.

Construction drawings are a precise set of engineered plans which show how the site is to be prepared for development and constructed. The construction specifications are a written description of the materials and methods to be used during construction. Typical documents which are a part of a CD set include:

- demolition and clearing plans
- layout plans
- grading and drainage plans
- sediment erosion control plans
- architectural plans
- site utility plans
- landscape plans
- construction details
- written specifications

The design decisions which are made in the conceptual and master planning phases of the site planning process are put into effect at this point. The CD set of drawings depicts the manner in which the development will actually be built and specifies the materials and methods which are to be used. Stormwater management should be included as a part of the CD materials.

The portions of a CD set which will have greatest effect on the overall success of an integrated stormwater runoff management plan include: layout, grading, drainage, sediment/erosion control, architectural design, landscaping, construction details, and specifications for materials and methods, as well as a plan for the operation and maintenance of the built facilities.

Although the focus of this manual is intended to be placed on runoff quality, there is a relationship between quantity of runoff generated and overall water quality. If the quantity of runoff can be reduced at any given point during its flow, the relative velocities and potential for carrying pollutants can be reduced accordingly. This level of planning will often include sediment and erosion control planning for use during and after construction. Details of the site plan should reduce the overall quantity of runoff from each portion of the site. The result will be a reduction of pollutants the runoff will be capable of transporting and improved runoff quality. This can be accomplished through a variety of methods of design detailing both site elements and architectural elements. An overall cost savings could be realized since the cost can be spread over many site components. In this manner, no individual element of the overall stormwater management plan will need to be overly large or expensive. A series of small incremental measures implemented throughout the site design will capture and treat the runoff generated as close to its source as possible as opposed to allowing a large accumulation to occur. A combination of preventive and control measures should be utilized for best effectiveness.

Implementation and Construction

Many measures can and should be taken during the implementation or construction of a development to prevent sedimentation and pollution from occurring on a construction site. These measures include following the sediment and erosion control measures outlined in the sediment and erosion control plan, proper storage of equipment and materials, clearing the minimum amount of land necessary at any given time, and providing protection for vegetation and waterways which are intended to remain undisturbed to ensure their integrity.

Operation and Maintenance

A successful operation and maintenance program will ensure that the development remains in good condition for a long period of time.

Once a development has been built and its facilities occupied, a successful operation and maintenance program will ensure that the development remains in good condition for a long period of time. An operation and maintenance program ensures that the ongoing activities are done in a manner which does not generate excessive pollutants or runoff. The failure to provide proper maintenance reduces the system's pollutant removal efficiency and hydraulic capacity. Lack of maintenance, especially to vegetative systems requiring harvesting or revegetating, can increase the pollutant load of runoff discharges.

The key to effective maintenance is to assign responsibilities to an established agency or organization, such as a local government or homeowners association, and to regularly inspect the system to determine maintenance needs. An even better tactic is to design a system that is simple, natural, and as maintenance free as possible.

The following sections will follow the site planning process from start to finish in more detail. Graphic examples are provided to help the user of this manual better understand this process.

Site Inventory & Analysis

The earliest consideration for stormwater management in the design process occurs through gathering, mapping and interpretation of information about the site during the *Site Inventory and Analysis* portion of the process. As the name indicates, this two-part process provides a systematic means of mapping information about the site and then getting it into a form which can be used as a tool during the design process.

Base Mapping

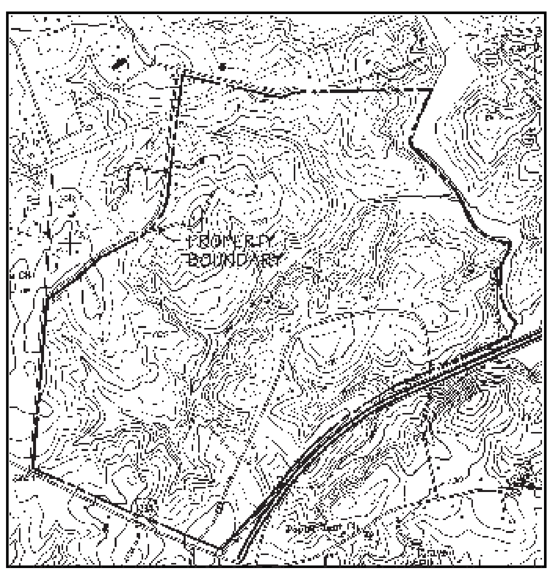
In order to understand the relationship of the existing natural systems to the changes which will occur as a result of development, the existing site conditions must first be mapped onto a *base map* of the site. The base map and the information which it includes will be used to make decisions about the design of the project.

Existing site conditions must first be mapped onto a base map of the site.

A base map depicts the two and three dimensional aspects of a piece of land and includes such components as site boundary and topography. This boundary and topography provide a basis for subsequent mapping of site characteristics and site plans.

Site Boundaries

The boundary for the site can usually be obtained from a survey, plat, tax map, or other source which will show the property lines and limits of the project area as well as other lines such as easements, rights-of-way, setbacks, buffers, utility locations, flood zones, or other lines which represent some sort of limit or boundary.



Site boundaries are usually available in the form of a survey.

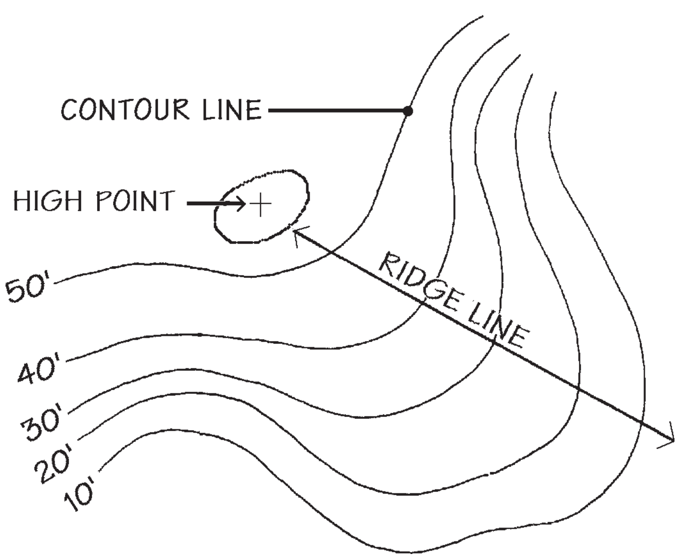
Topography

Once a boundary establishing the two-dimensional extents of the site has been mapped, the topographic information, which expresses the three dimensional characteristics of the land, can be added. The basis for topographic information is a contour, or a line on the map, which represents points of common elevation above a given base plane. Contours can be mapped at any convenient interval which will reveal sufficient information about the lay of the land.

An understanding of the site topography is the basis for understanding the movement of water on the site.

An understanding of the site topography is the basis for understanding the movement of water on the site. Water runs downhill; it will flow in a perpendicular direction from a contour of a higher elevation to one of a lower elevation. Contours which are spaced close together on a topographic map represent land which is steep. Flatter land has contours which are spaced further apart. As land becomes steeper, runoff flows faster, and has more energy to erode soil and to carry pollutants and sediments. For this reason, the topography is useful to depict not only the direction of flow of water on a site, but also to gain an understanding of its velocity. Whenever the topography of the land is changed to accommodate development, there will be a response to the changes in the flow patterns or velocities of surface runoff.

Topographic information can be obtained from a variety of sources. The most common means of obtaining site topography, or topo, is from sources such as city or county engineering or planning departments. The USGS also has topographic maps which cover nearly the entire state at a variety of scales. The most common scale is 1"=2000' found on a 7-1/2 minute quad map. This scale of mapping is usually only suitable for site planning of large sites of about fifty acres or more. For smaller sites topo should be sought which is at a scale of 1"=100' to 1"=400' or larger. Larger scale topo maps are generally able to show a greater amount of detail and accuracy. Site planning for stormwater management will benefit from the greater detail.



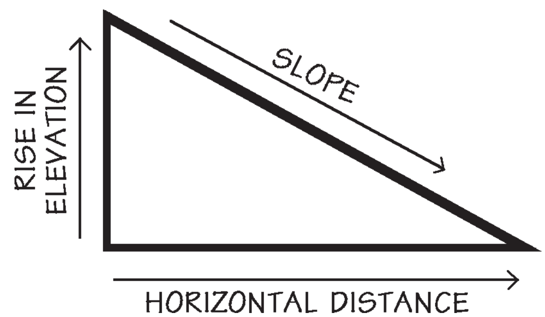
Topography is a two dimensional representation of a site's landforms .

Topography from a USGS quadrangle (quad) map.
Scale of these maps is usually 1"=2000'.

Sometimes there is no existing topographic information available for a site, or that which is available is not at a scale which is useable. In circumstances such as these, it may be necessary to have topography generated by a survey or interpreted from aerial photography. For very small sites, topography can sometimes be estimated.

Slope of the Land

The slope or steepness of the land can be readily interpreted from the topographic map by measuring the horizontal distance between the contours. Since the contours are at a specified vertical interval, the horizontal distance between them will indicate the steepness of the surface of the land between the two contours. It is important to know how the contours relate to the steepness or slope of the land when designing a project. Changes to make the land steeper or flatter will be made by adjusting the contours closer together or further apart. Land which is less steep will require less change for land uses which are relatively flat such as buildings and parking. Siting land uses onto the existing topography will require less change to the land in the form of grading and will result in less change to natural drainage patterns.



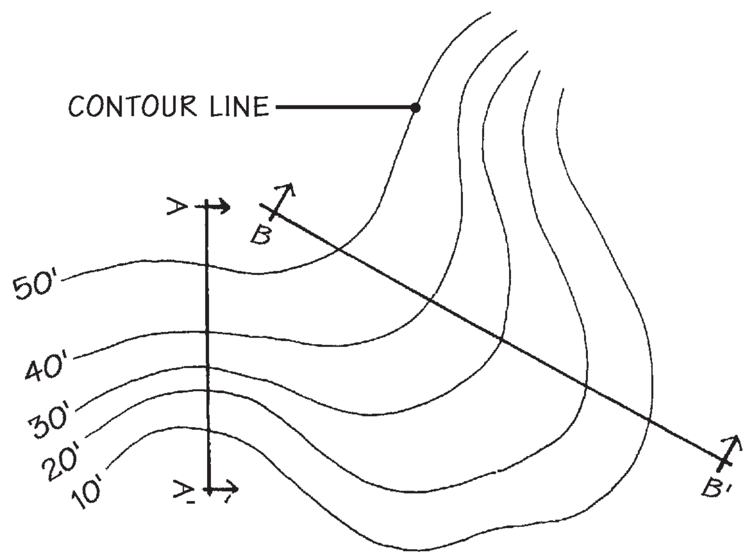
Slope of the land is expressed as a ratio of horizontal to vertical (example 4:1) or a percentage (example 25%). The slope is the rise in elevation divided by the horizontal distance.

The degree of slope will influence the velocity of runoff and its ability to erode soil or carry pollutants to surface waters.

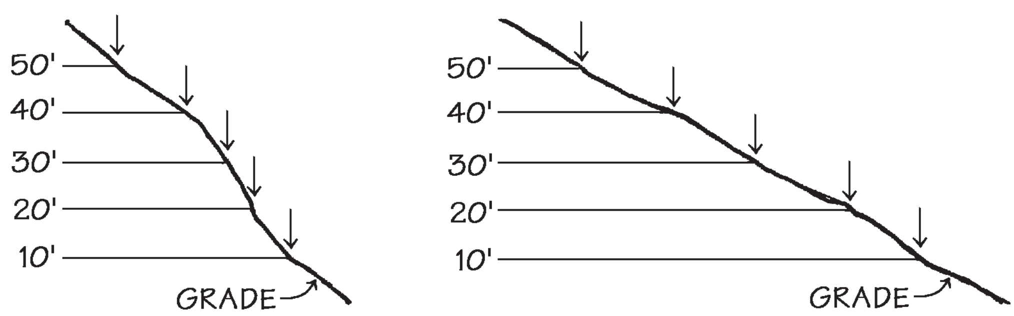
It is very important to consider slope when designing a stormwater management system. The degree of slope will influence the velocity of runoff and its ability to erode soil or carry pollutants to surface waters. Developed areas which have steeper slope allow runoff to pass through more quickly, increasing the potential for downstream flooding. Since the runoff passes through an area of steep slope more quickly, there is less chance for infiltration or filtering. When steep slopes are disturbed during development there is a potential for erosion to occur. Also, steeper slopes are more difficult to stabilize once they have been disturbed. If possible, it is best to leave areas of steep slope undisturbed. If it is not possible to leave these areas intact, the alternative is to break up the length of the slope, if developed, so that runoff velocities will be slowed.

Slope Map

A *slope map* can be prepared which will indicate which areas of the site have slight, moderate or severe slope limitations. The degree of slope severity will differ depending upon factors such as the erodibility of soil types on the site and the type of land use which is intended. For some areas, a ten percent (or 10 to 1) slope may be considered steep - that is a slope which results from a vertical rise of 10 feet over a distance of 100 feet. In other areas which have very stable soils, a slope of 20 percent may not be considered steep by local standards. This map layer will serve as a valuable tool during the site planning process to assist in the location of land uses.



Plan view of contours.



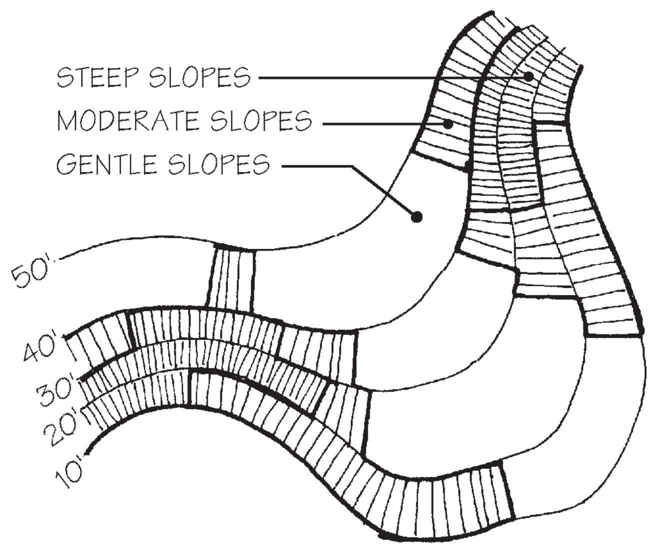
Section A-A'
Steeper slope.

Section B-B'
Flatter slope.

Sections through contours.

A slope map is constructed using the base map topography. The contour lines of the base map represent points on the site which are at a common elevation above a horizontal base plan. The distance and spacing between contours is a measure of the slope of the land. Contours which are closer together indicate steeper slopes, contours which are further apart represent flatter slopes. The degree of slope (or percent or ratio of slope) is really a relationship between the vertical distance (change in elevation) of the contour interval and the horizontal distance which can be measured on the base map.

One method of indicating steeper slopes on a map is by hatching or shading. A completed slope map which uses this technique will have the most severe slope limitations shaded darkest, lighter areas of the map represent the areas with fewest slope limitations.



A slope map will show steeper slopes shaded dark and gentler slopes left light.

Drainage Features and Site Hydrology

Drainage patterns are the direction and pathway which surface water will take over the land when runoff from rainfall occurs.

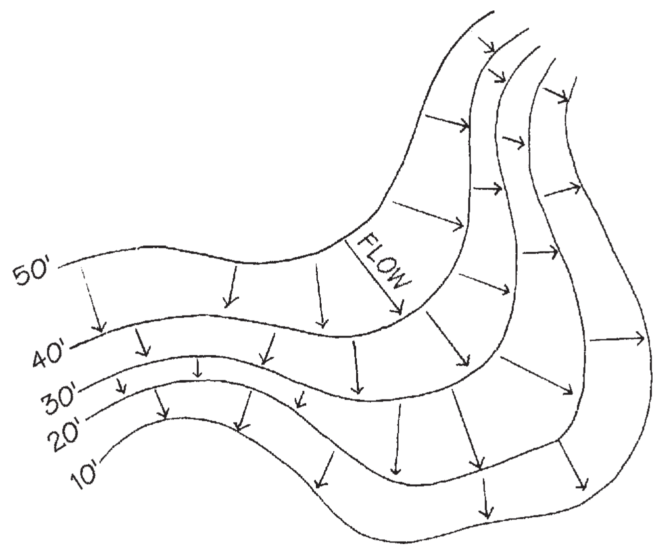
The description of the *drainage patterns* and other features related to the activity of water on a site are collectively known as the *hydrology*. Drainage patterns are the direction and pathway which surface water will take over the land when runoff from rainfall occurs. Sometimes the runoff collects into channels and is carried to streams or to lakes. Other times, the rainfall will not become runoff and will be absorbed or infiltrated into the land.

Water flows in a direction perpendicular to the contours of the land. The patterns of surface flow consist of areas of standing water, sheet flow, channelized flow and in certain circumstances a combination of these conditions.

Drainage features

The hydrology or drainage features of a site are determined by the characteristics of the land such as topography, soils characteristics, and vegetation patterns. The climate of the site will also influence hydrology with rainfall quantity and evapotranspiration rates. The features of a natural drainage system include: natural drainageways, depressions, wetlands, floodplains, highly permeable soils and vegetated areas.

The hydrology or drainage features of a site are determined by the characteristics of the land such as topography, soils characteristics, and vegetation patterns.



Water always flows perpendicular to contours.

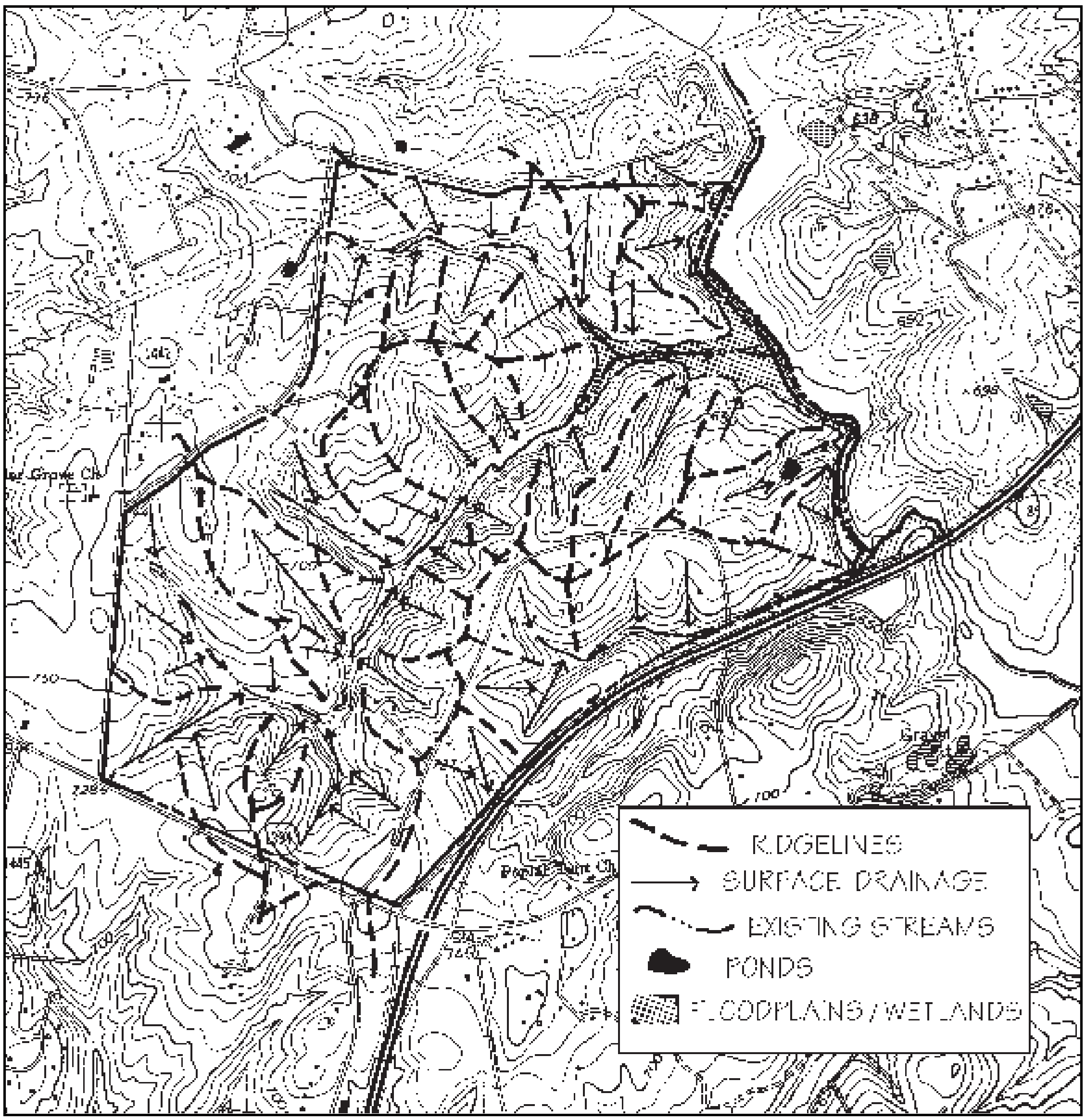
To gain an understanding of the surface hydrology of a site, its features can be mapped using symbols for streams, wetlands, standing water, infiltration areas, floodplains, and other existing features. Direction of flow can be indicated with arrows. The level of detail necessary in this mapping can be very general at first for conceptual level planning, then increased in detail as the planning process continues and more information is needed.

It should be a goal at the outset of the design to preserve and maintain existing drainage patterns and hydrology of a site.

It should be a goal at the outset of the design to preserve and maintain existing drainage patterns and hydrology of a site. An understanding of the functions of the natural drainage features on an undeveloped site will help to realize their influence on runoff quality. In a natural drainage system the network of channels, depressions, floodplains, and infiltration areas has had time to become stabilized. When land is developed and the natural drainage patterns are changed, the surface flow must still be accommodated in some manner. The curbing, catch basins, and pipes found in a typical development design replace natural channels in their ability to collect and carry flow quantity but offer little in the control of water quality. It is difficult to take advantage of the site hydrology which is already in place without first understanding the components and functions of a natural existing drainage system.

Drainage basins

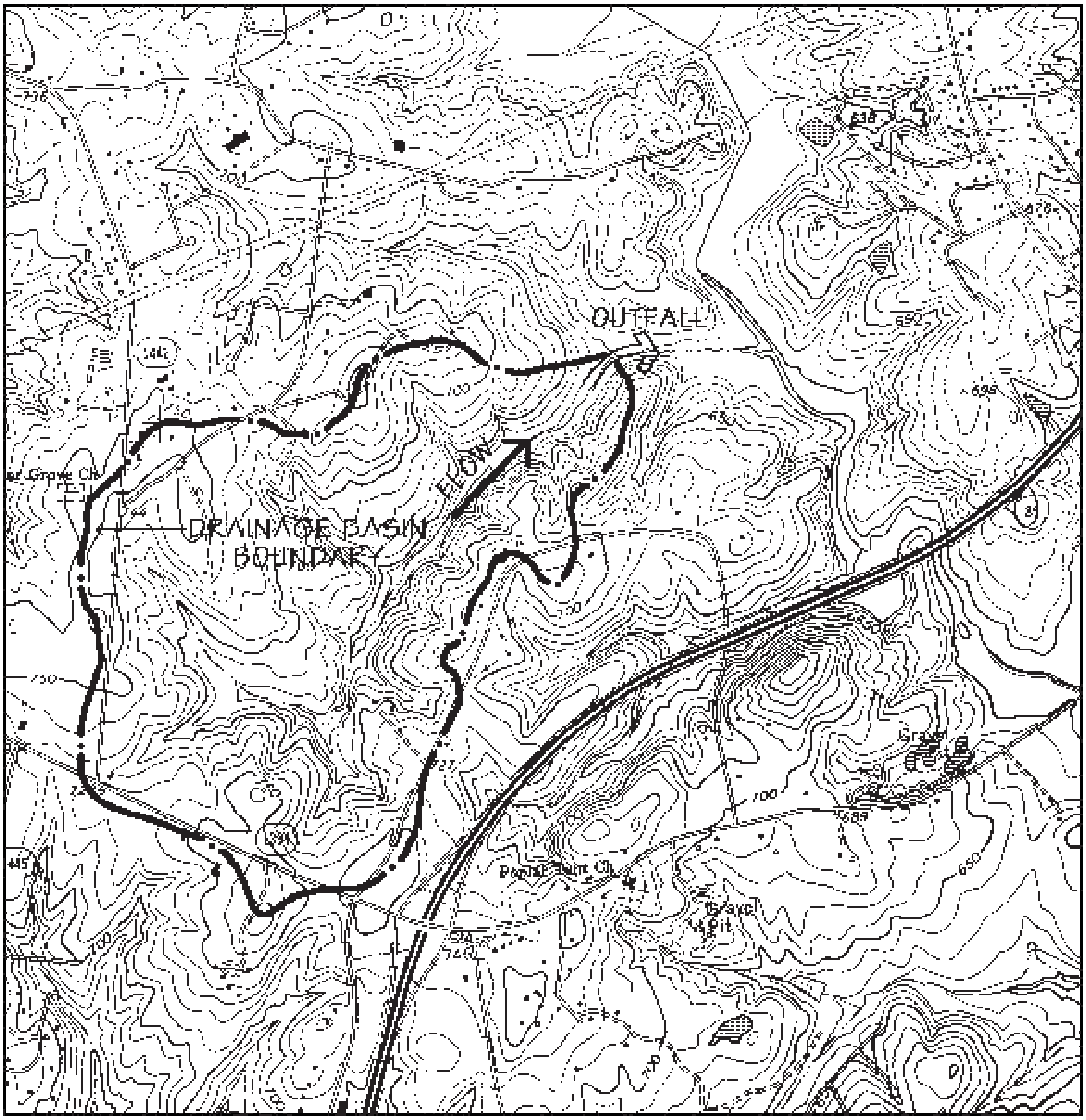
Once the flow patterns and drainage features have been mapped, the site can be divided into drainage basins. A drainage basin is the most basic element of a stormwater management plan and can be defined by identifying the limits of the area of



A drainage features map shows the components of the existing natural drainage system.

A drainage basin is the most basic element of a stormwater management plan and can be defined by identifying the limits of the area of topography which will contribute runoff to a single outfall point.

topography which will contribute runoff to a single outfall point. The limits of each discernible drainage basin are identified by locating the high points, ridge lines and saddle lines of a site. If a line is drawn which connects these points, it will represent at least a portion of a drainage basin boundary. A drop of rain falling onto the site on one side of the line or the other will flow into whichever basin is bounded by the line on that side. An individual drainage basin can be large enough to encompass an entire site and the surrounding area, or small enough that a single site may have several within its boundaries, a very small site may only have a portion of a basin. Several individual drainage basins may flow together to form a river basin, or watershed.



A drainage basin is defined by the limits of the area which contributes runoff to a single outfall point.

The quality of the runoff which is contributed by each drainage basin within a watershed will have an effect on the water quality which occurs at the outfall. Areas which are near the upper reaches of basins typically offer the greatest opportunity for preventive measures in site planning design and are typically less likely to be subject to flooding. Areas at lower portions of drainage basins offer opportunities for control measures which are intended to capture runoff from a wide area. The lower portions of a drainage basin are the recipients of runoff from the entire basin and may be subject to increased flows and possible flooding as upper areas of the basin are developed. Measures may be taken during development to prevent this from occurring.

The amount of runoff which is generated at one time within a given basin is a result of several factors: amount of runoff contributed by upstream areas, slope of the land, soils characteristics, land cover characteristics, regional climatic conditions and effectiveness of existing surface runoff controls among others.

Site topography and drainage patterns can be used to divide a site into its component sub-basins for more detailed design.

Soils

Characteristics of soil types which are important to consider during the site planning process include: permeability, wetness, slope, strength, erodibility, and depth to bedrock.

Every site will have soils characteristics which must be understood in order to design an effective stormwater management system. Soils are categorized and mapped by the USDA-NRCS based upon their characteristics. There is a close relationship between soil types and their position in the landscape. Characteristics of soil types which are important to consider during the site planning process include: permeability, wetness, slope, strength, erodibility, and depth to bedrock. These characteristics will influence the placement of land uses, including stormwater, on those portions of the site that would be best suited to each use.

Soils information is obtained from NRCS Soil Surveys which are prepared on a county by county basis.

Adapted from USDA-NRCS Soil survey for Cabarrus County, NC

Soils interpretation

Soils information for a site is available for most counties of North Carolina from the local NRCS office in the form of a county soil survey. A soil survey contains descriptions of the soil types which occur throughout the county and maps of where each soil type occurs. The maps are typically at a scale of 1"=2000' feet which corresponds to the scale of 7-1/2 minute USGS quad sheets. This scale of mapping is most useful for the planning of larger sites, however even for small sites, a general understanding of the nature and properties of the soils will be helpful for conceptual planning.

In order to make use of the information found in the soil survey, it will first be necessary to determine the location of the site on one of the survey maps. The information shown on the maps consists of soil series boundaries and symbols in the form of letters or numbers which represent each soil type (referred to as a mapping unit or soil series). Once the site location has been identified on the map, the symbols for the various soil types which occur in the vicinity of the site should be noted.

The remainder of the soil survey consists of descriptions of each soil type and a number of charts which provide information about the soil type, its characteristics, and its limitations for various land uses. This information can be used to determine the limitations for each of the soil types found on the site and their suitability for various plan components.

It is important to consider the characteristics of the different soil types on a site when designing a stormwater management system:

- Areas which are intended to be used for infiltration function best when the soils are deep and well drained.

- Areas which are to be used for surface water storage, such as a wet pond, function best when the soils do not drain as well.

- Soil types which are most suitable for development will often occur on broad ridgetops and gentle sideslopes.

- Soils which are at lower elevations such as in floodplains, depressions, or along drainageways will usually present limitations of wetness.

- Soils which occur on steep sideslopes can often be observed to have limitations including slope, shallow bedrock, or erodibility.

Existing Vegetation

Observing and understanding the relationship of the vegetation patterns to other site characteristics can be beneficial to the appropriate siting of land uses.

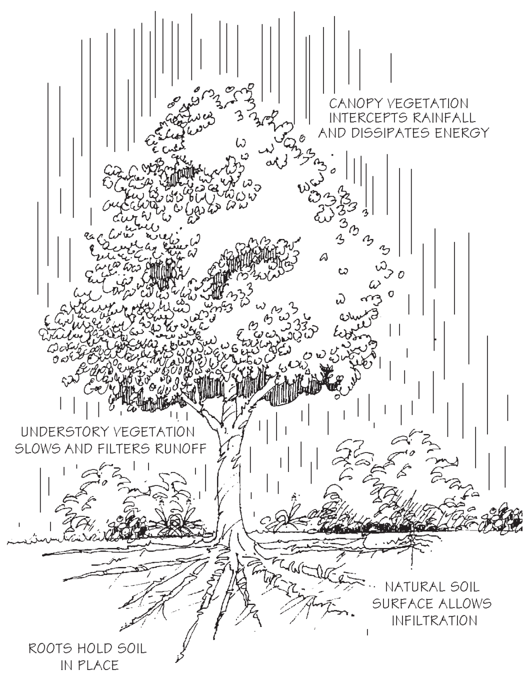
Vegetation patterns on an undeveloped site can reveal a great deal about the nature and properties of the development conditions of the site. The plant species and communities which occur on the site are indicative of soils conditions, drainage conditions, history of land use, or other factors which have been influencial to their presence. Observing and understanding the relationship of the vegetation patterns to other site characteristics can be beneficial to the appropriate siting of land uses.

Although general vegetation patterns can be determined from aerial photos, the best method of evaluting the vegetation on a site is to conduct a site visit as early in the process as possible. In this manner, the vegetation can be evaluated for its quality as well as its presence. The appearance of vegetation can vary significantly from one season to the next throughout the year.

An inventory of the existing vegetation on a site can be prepared from aerial photography, surveys, or observation.

The existing vegetation on a site should be identified and left undisturbed where possible as an important part of stormwater system design. From a stormwater runoff standpoint, existing vegetation serves a very important purpose in slowing runoff, encouraging infiltration, soil stabilization and providing evapo-transpiration of captured runoff. This will benefit the overall goals for runoff water quality in several ways:

- Areas which are left in a naturally vegetated state reduce the total impervious surface area. This reduces the quantity of runoff being generated and maintains the natural porosity of the site to allow for infiltration.
- The natural vegetation can be incorporated into filter strips and buffers to surface waters to help slow runoff and to capture pollutants.
- The intact canopy vegetation will intercept rainfall and disperse its erosive energy before it reaches the ground surface.
- Runoff can be directed into the vegetated areas for infiltra-tion and absorption.
- Intact root systems hold soil in place and reduce surface erosion.



Some of the stormwater benefits of existing vegetation

Vegetation Patterns

The general patterns of site vegetation masses can be mapped from various sources including surveys, field reconnaissance, and aerial photography. The location of vegetation masses can serve as a basis for conceptual planning and provide a means of refining detail throughout the design process. Vegetation is often a fairly reliable indicator of subsurface conditions. Areas which have been recently used for agriculture or a similar land use will be typically open or in some stage of recent successional growth dominated by upland species of plants. This will usually indicate well drained soils conditions which are not too steep and which do not have severe shallow bedrock limitations. Generally, the older the growth on a site, the more severe the conditions would be expected to be for agricultural use and could be expected to be difficult to use for other types of land use as well.

If a site is wooded, the type of trees growing on the site can be indicative of certain subsurface soil and groundwater characteristics. Typically, if the vegetation is dominated by upland pines, then the soils conditions are generally favorable for development. Since these pines tend to have a deep tap root they will usually be found in an area which has deep soil with relatively few limitations which would limit growth such as wetness or shallow bedrock. Hardwoods, on the other hand will typically have a shallow spreading root system which is tolerant of more severe conditions. Hardwoods, being somewhat more adaptable than pines, are typically found in conditions such as those which have shallow bedrock or a water table close to the surface. Large hardwoods indicate that it has been a long time since the land was cleared, even for timber. Some areas of hardwoods occur on steep sideslopes which would otherwise be well suited to pines if they could be readily planted or harvested as timber. These slopes, when allowed to vegetate naturally, have resulted in hardwood stands.

Where possible, vegetation which is in a natural and relatively undisturbed state should be kept intact to serve as open space or buffers for the development. This vegetation serves several purposes:

- it reduces the percentage of impervious area on-site
- serves as a filter for overland surface runoff
- serves as an area of infiltration.

Large trees provide an enormous amount of evapotranspiration which if incorporated into the stormwater control system can provide a means of reducing the quantity of surface runoff generated by a site.

Composite Analysis

A composite analysis combines and summarizes the information gathered and interpreted during the inventory process

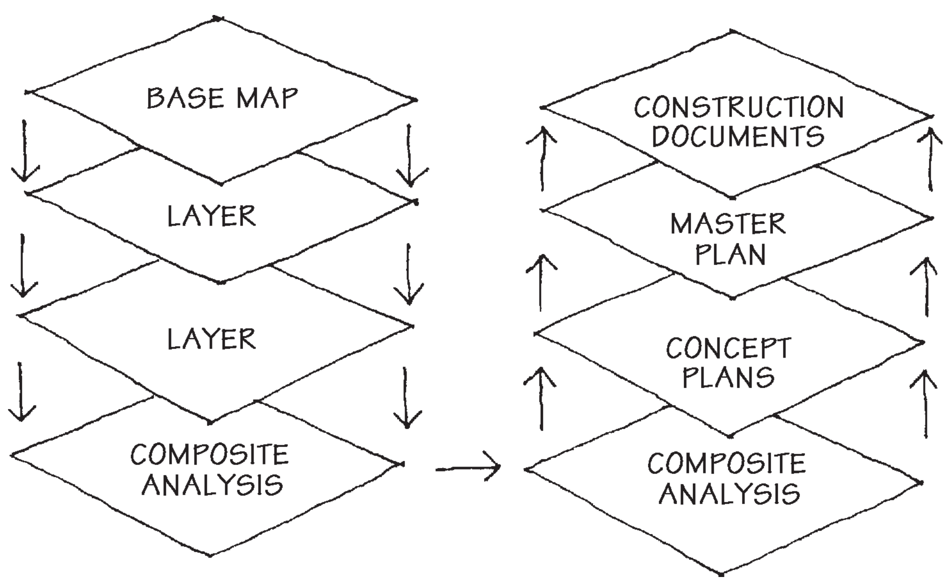
A *composite analysis* is a drawing which combines and summarizes the layers of information previously gathered and interpreted during the inventory process, beginning with a base map of the site. As each layer of information from the inventory is added to the base map, a series of zones will become apparent which reflect the characteristics of the included layers. The composite analysis provides a means of simplifying a large quantity of complex information into a form which can be used as a design tool.

Since it will be used as a decision-making tool during the design process, the composite analysis provides an ideal opportunity to identify and emphasize the importance of the existing natural drainage features on a site.

In addition, this stage will help developers to see the limitations of the site. Some portions of the site will have relatively few development constraints, while others will have many. Layers which will present physical limitations to development include: steep slopes, soils constraints, and vegetation patterns. Other layers will dictate where development can or cannot occur regardless of physical limitations; these areas include property lines, setbacks, rights-of-way, easements, buffers or other restricted zones.

The composite analysis should note site features which offer advantages as well as disadvantages to development.

The composite analysis should note site features which offer advantages as well as disadvantages to development. Attractive views, access points for circulation, access to utilities, site amentities, or climatic features, as well as those portions of the site which have existing drainage features and significant vegetation should be noted so that these elements can be incorporated into the site plan.



One method of interpreting information during the site inventory and analysis is the overlay method.

Disadvantages such as odors, noise, unattractive views or proximity to conflicting land uses should be taken into consideration as well.

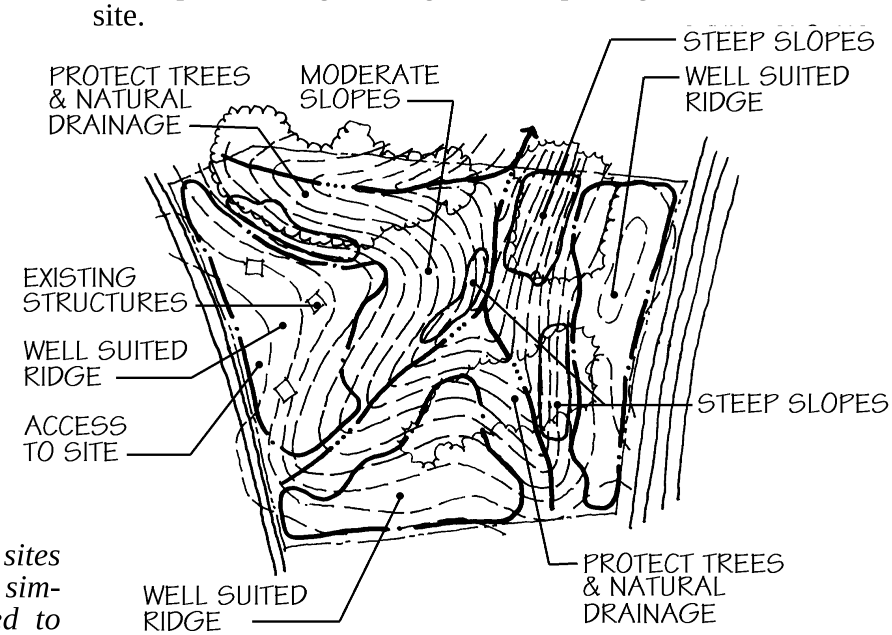
Depending upon the complexity of the program for development and the existing conditions found on a site, many additional inventory layers can be prepared to map out information which is pertinent to the specific site. Such additional information may include surrounding land uses, historical resources, ecological resources, zoning information, climatic information, visual inventories, utilities, access, or any other information which needs to be considered during the design process. Some of this additional information will not relate directly to decisions regarding stormwater but will influence other aspects of the design.

Once the various layers of information have been gathered and brought to a common scale, they can be overlaid and evaluated to determine which portions of the site are best suited to the development of each component of the intended land use. The process of overlaying the various layers of information can be conducted manually with clear overlay sheets, or digitally by using a computer.

A composite of the site inventory drawings will reveal the location and severity of constraints to proposed development.

A composite of the site inventory drawings will reveal the location and severity of constraints to proposed development. Those areas which have the fewest or least severe constraints would typically be best suited to most components of a development program. Constraints may dictate adjustments in the design.

For very small sites or sites which are not complex, a simpler method of evaluating development constraints can be used, especially by individuals with significant development experience. The overlay method is presented here as an illustration of the process of gathering and interpreting information about a site.



For very small sites or sites which are not complex, a simpler method can be used to evaluate development constraints and opportunities.

Other Information

In addition to the existing natural features of the land, a number of existing man-made features may occur on a given site and will need to be considered during the design process. These features include existing structures, roadways, utilities, surrounding land uses and features of the site such as cemeteries or other areas which must remain undisturbed.

A typical site will have a history of land use over the years. Each of the previous uses for the land will have left some indication of the changes which have occurred since the land was in its natural and undisturbed state. Some of these features of the site are permanent and must be included as a part of the site plan, others can be changed to accommodate the new site plan.

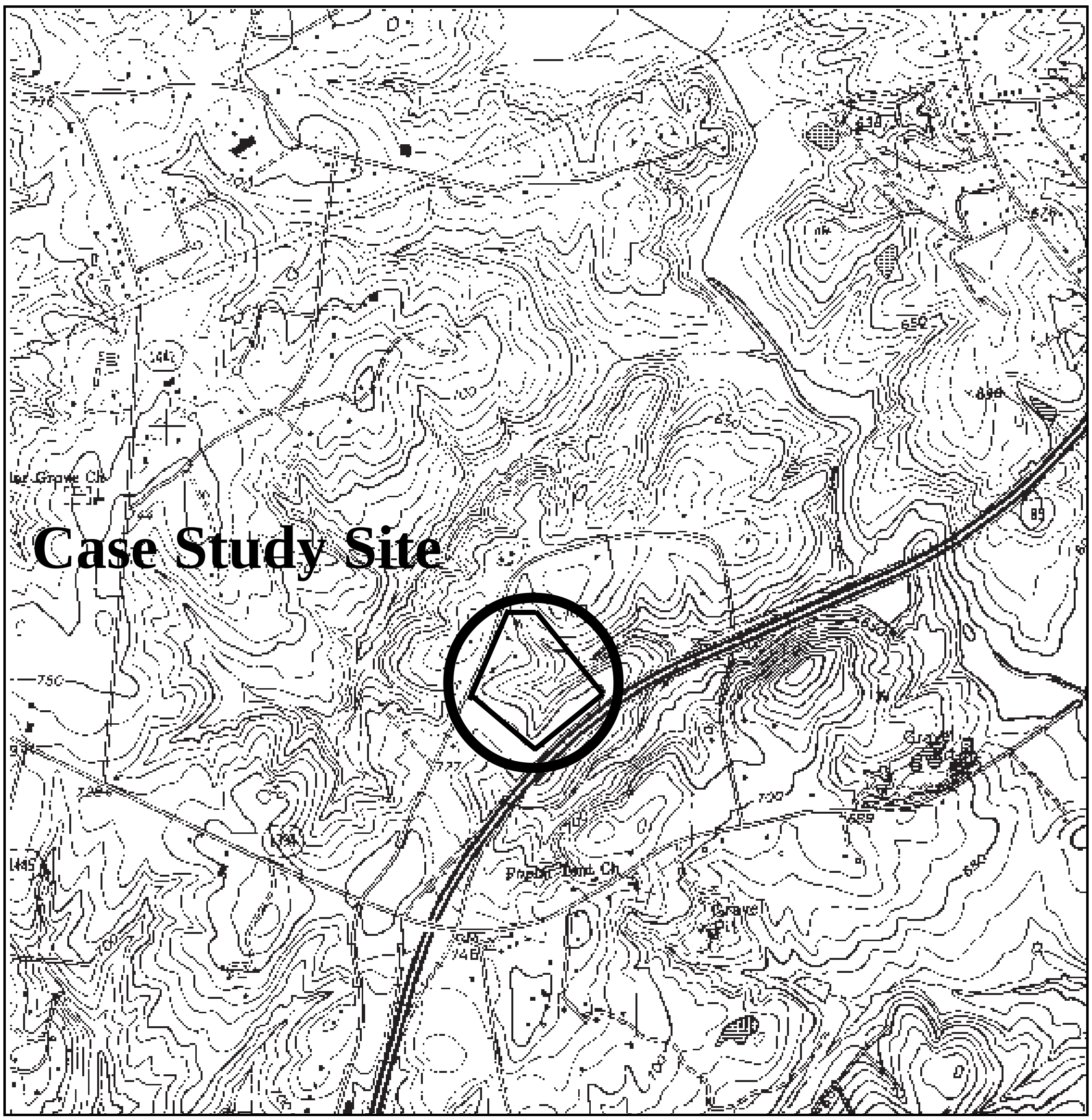
The features which must remain undisturbed will have a significant influence in the design of a stormwater system. Grading and other changes to the site which direct or store surface flow will not be able to be made in these areas. In order to provide for stormwater management the flow must be directed around these areas or be relocated in a manner which does not require their disturbance.

There may also be an existing man-made surface runoff system which must be considered in the site design. This situation is often found on in-fill development.

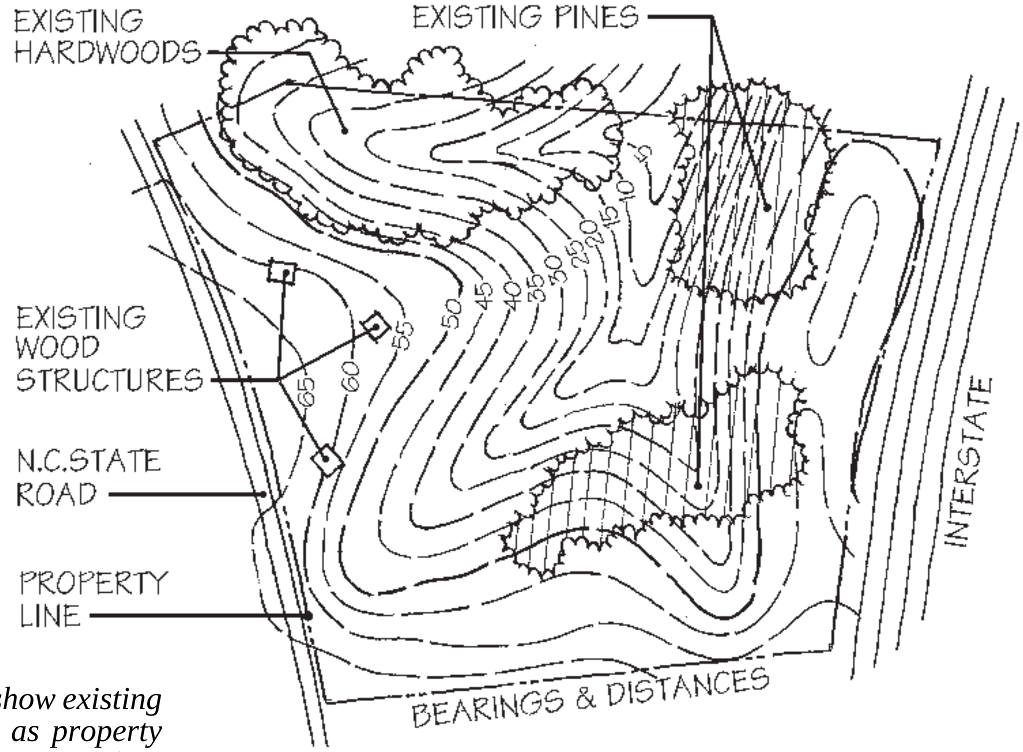
Case Study Site

A small 30 acre case study site will be used throughout the remainder of the manual to illustrate the site planning process. This site is part of the much larger tract of land previously illustrated throughout the Site Inventory and Analysis section. The larger tract was used to describe some of the sources of information which are readily available for a parcel of land. The location of the 30 acre tract within the larger tract is shown below.

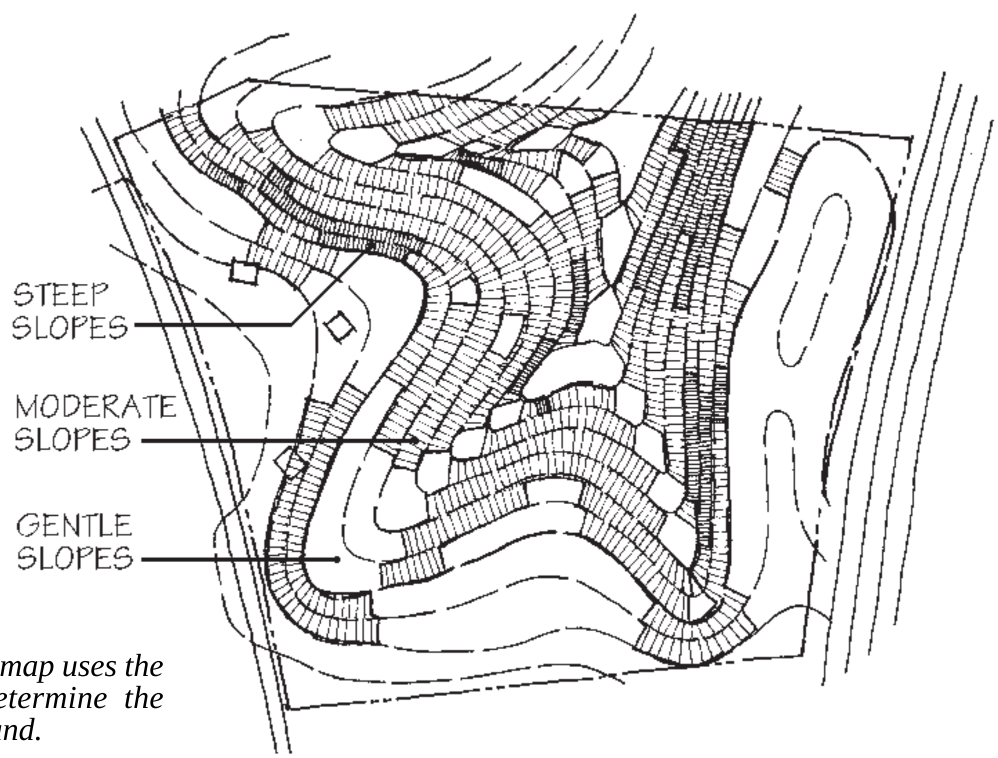
The case study site will illustrate the use of the overlay method of site inventory and analysis and then utilize this information to illustrate how a site plan is developed for the parcel.



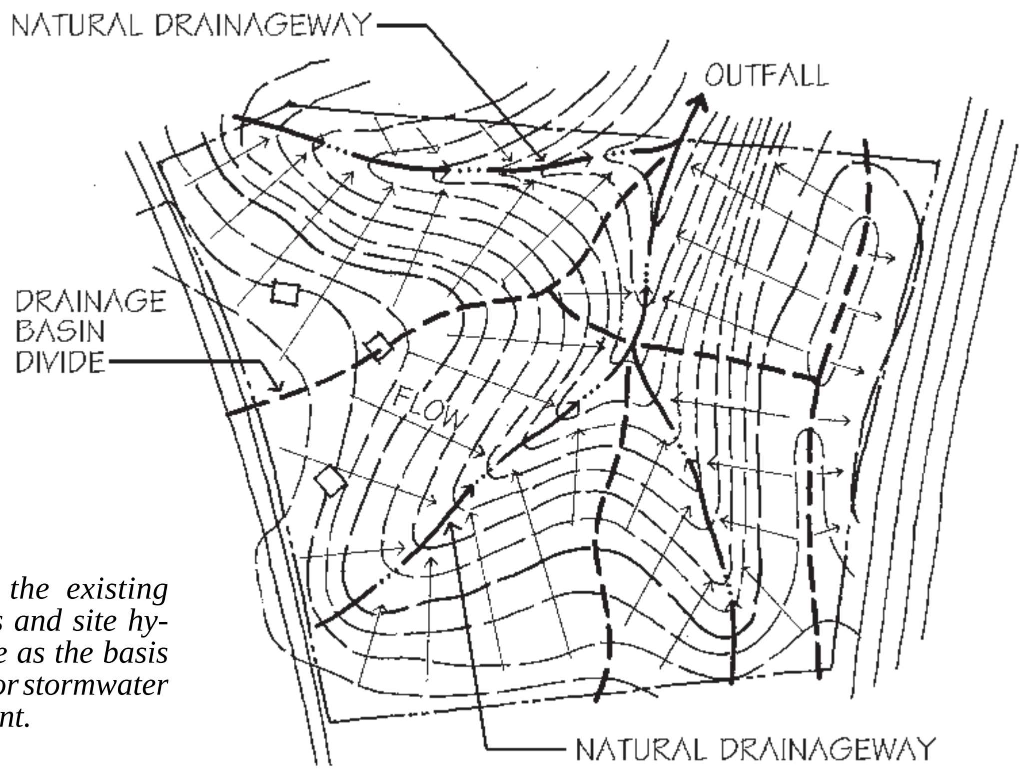
Location of 30 acre case study site within larger parcel.



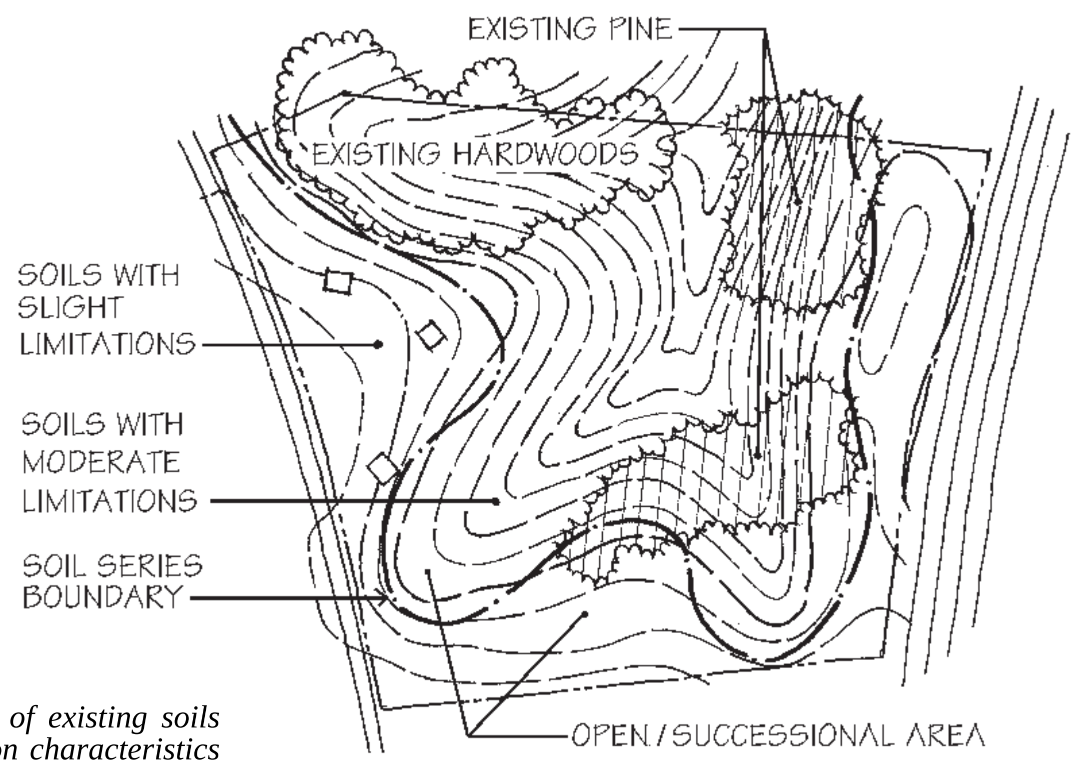
A site survey will show existing site features such as property lines, topography, vegetation, and roadways. This layer will serve as a base map for further inventory, analysis and plan development.



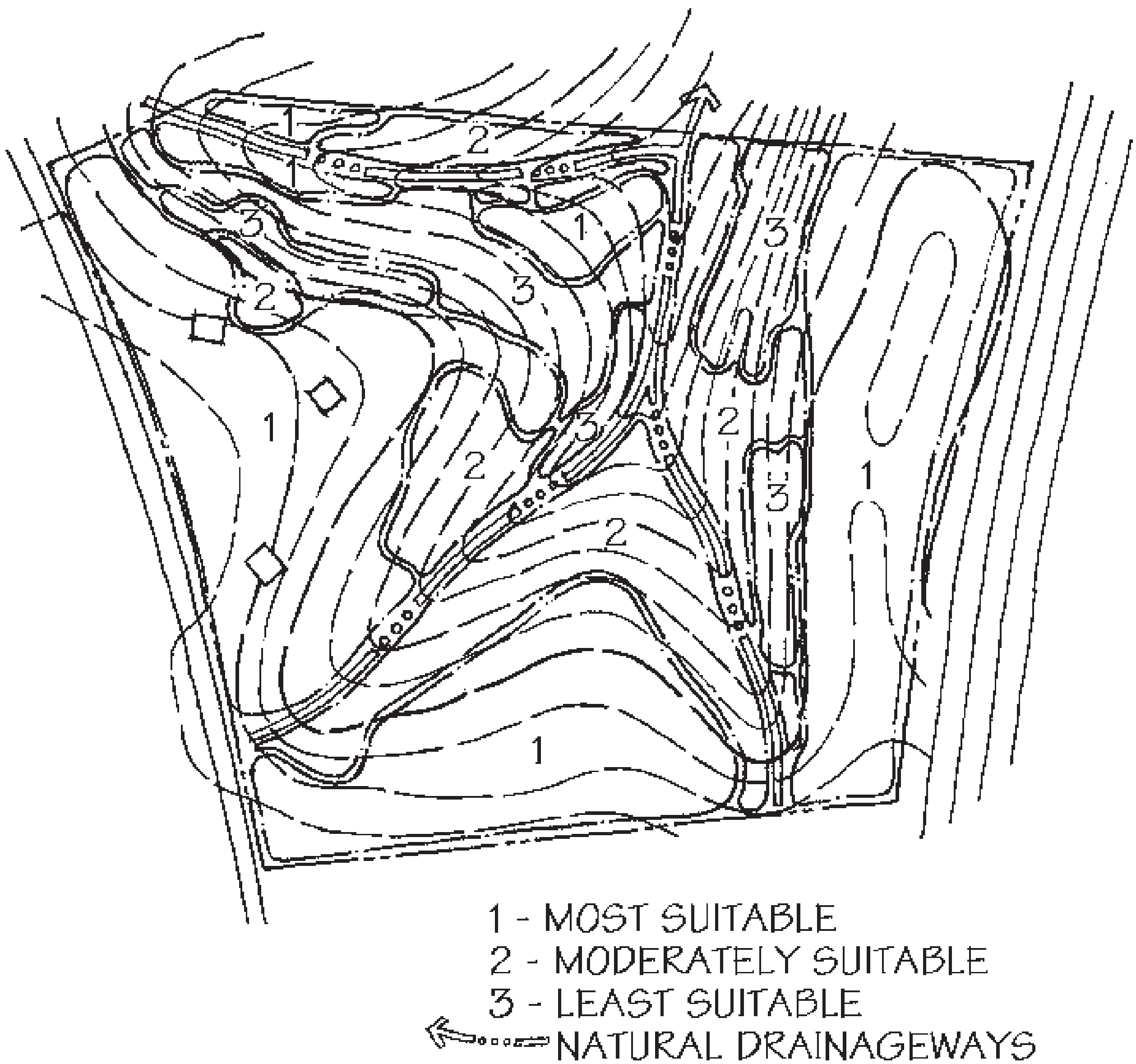
A slope inventory map uses the topography to determine the steepness of the land.



An inventory of the existing drainage features and site hydrology will serve as the basis for site planning for stormwater runoff management.



An inventory of existing soils and vegetation characteristics will be useful to site planning decisionmaking.



The various layers of information can be overlaid together at a common scale to create a composite inventory map This information is then interpreted or analyzed to determine the suitability of each portion of the site for the proposed development.

The composite analysis map or development suitability map defines zones within the site which will offer development opportunities or constraints.

Conceptual Site Plan

Conceptual planning is a two-step process - identification of a *program for development* and the preparation of a *conceptual site plan.*

Program for Development

A *program for development* identifies the components and elements which will be included in the site plan for a development. Before the elements can be physically located on a design, they must be defined in terms of their size, number, and requirements. A program is a listing of the various components of the plan and a description of their sizes and quantities. The size and placement of individual elements on a site plan (such as buildings, roads, and parking) are often dictated by standards, zoning requirements or other regulations. Additionally, the programming for most land uses will be determined by influences such as market demand for a particular land use or preferences, goals and objectives of the developer.

A program for development identifies the components and elements which will be included in the site plan for a development.

Typically included in this phase of site planning are allowances for amenity areas or open space. Consideration should also be given to the space requirements for stormwater runoff management components. With increased pressure to maximize use of a site, stormwater planning is often not considered until late in the development process and must be fit into the plan at the expense of proper design. If allowances for stormwater are made earlier in the site planning process, they can be integrated more thoroughly and thoughtfully into the design. When incorporated as a part of the overall program for the site plan, stormwater management can be implemented in a more efficient and cost effective manner.

If allowances for stormwater are made early in the site planning process, they can be integrated more thoroughly and thoughtfully into the design.

Commercial/Retail/Office:	8 acres		
Commercial		17,000 sq. ft. building	110 parking spaces
Retail		3,500 sq. ft. building	40 parking spaces
Restaurant		5,500 sq. ft. building	90 parking spaces
Office		6,000 sq. ft. building	80 parking spaces
Convenience Retail:	1 acre		
		2000 sq. ft. building	10 parking spaces
Single Family Residential:	12 acres	24 lots or 40 cluster units	
Park/Open Space	9 acres		
Total area of site:	30 acres		

A program for development lists quantities of plan elements and the land area allocated to each.

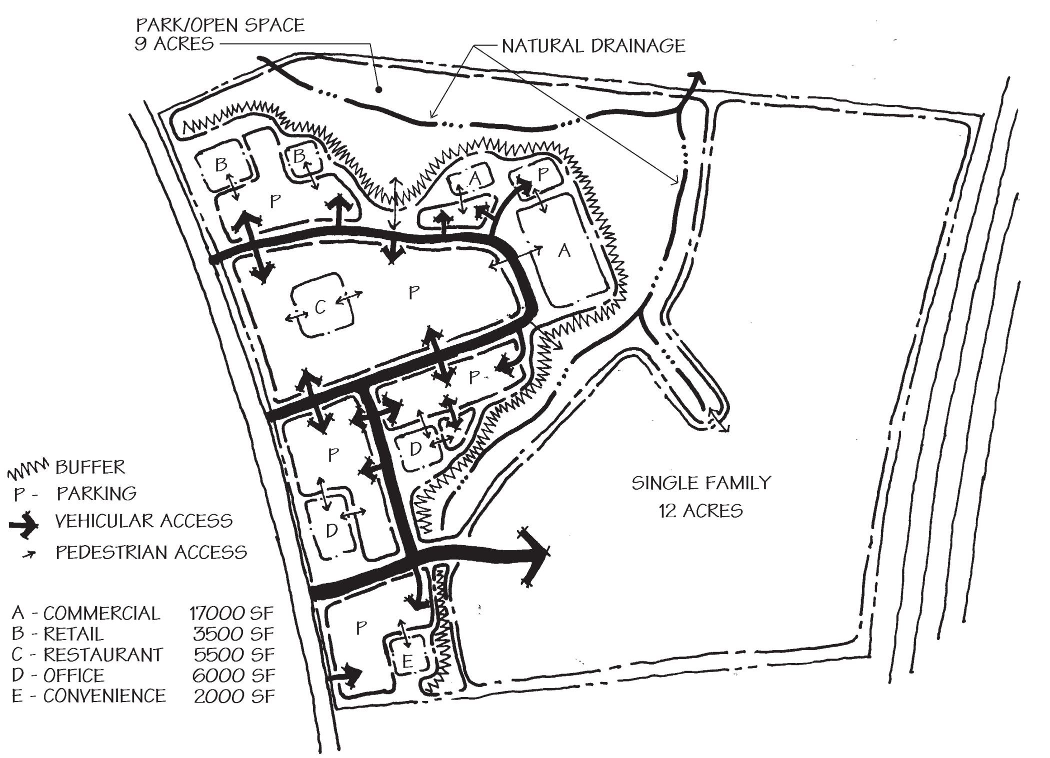
Spatial Relationships Diagram

A drawing known as a *spatial relationships diagram* is an intermediate step which is often used to translate the descriptions of plan elements in the development program into a form which can be drawn onto a site plan and built. A spatial relationships diagram is a scale drawing in which individual plan elements are drawn as shapes and forms approximating their intended size. For example if a building is intended to be 10,000 square feet in size when it is built, then a shape (maybe a square) would be drawn on the diagram which represents this amount of area. As each element is drawn, the diagram can be used to indicate the relationship of each element to others in the diagram.

Some elements of the program will need to be shown close to one another. For example, a house would be situated close to a garage. Other elements will need to be spaced with some distance between them. Buffers and barriers can be represented by symbols on the drawing to separate uses where necessary. Connections should be shown between uses which represent circulation for pedestrians or vehicles. Connections should be shown, for example, between an existing road and proposed parking for vehicular access or between buildings where a sidewalk would occur for pedestrian circulation. These can be represented by arrows.

A spatial relationships diagram is a scale drawing in which individual plan elements are drawn as shapes and forms approximating their intended size.

The diagram should show where open space and amenity areas are intended as a part of the plan. Allowances should be made in the drawing to accommodate the runoff or pollutants which are expected to be generated by the various plan components. When completed, the spatial relationships diagram should look similar to a plan view of the proposed development.



Siting Land Uses

The topographic and hydrologic characteristics of the site should be utilized to fit each use to the site.

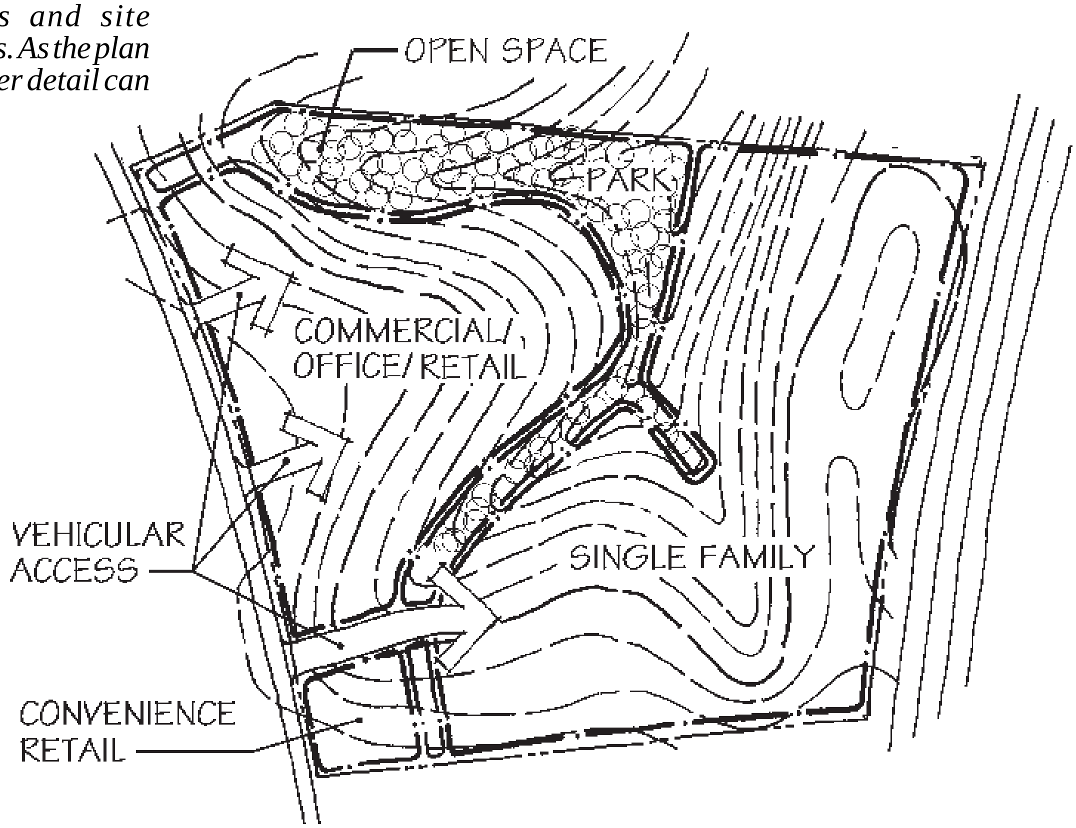
Impacts can be reduced by siting plan elements in a manner which requires less change of the site's natural topography and vegetation.

A concept plan begins with a generalized siting of land uses based upon their size requirements and site characteristics. As the plan evolves, greater detail can be shown.

The spatial relationship diagram, while drawn to a relative scale should be flexible enough that it can be adapted to the three dimensional and physical constraints of the site indicated by the site analysis. At this stage of conceptual planning, the details of the design of individual elements have not yet been resolved but the conceptual sizes, relationships and interconnections begin to take form and are fit to the site.

It is best to adapt the design of plan elements to the site. When the design of elements cannot be adapted to the site, the site must be changed to accommodate the element. The topographic and hydrologic characteristics of the site should be utilized to fit each use to the site. Wherever possible, the existing natural drainage system should be recognized as the beginning point of the design for stormwater management.

Siting land uses in areas which are best suited to them will allow a greater portion of the site to remain less disturbed. Areas which have better soils, gentler slopes and are relatively unvegetated are generally better suited to most types of development land use, such as roads and buildings, and require less modification in order to be used. This is a very important consideration for the preservation of existing natural drainage features. The more land which must be disturbed on a site, the greater the impacts will be to the natural systems. Impacts can be reduced by siting plan elements in a manner which requires less change of the site's natural topography and vegetation.



Reducing the amount of impervious surface where possible will result in a reduction in runoff quantity.

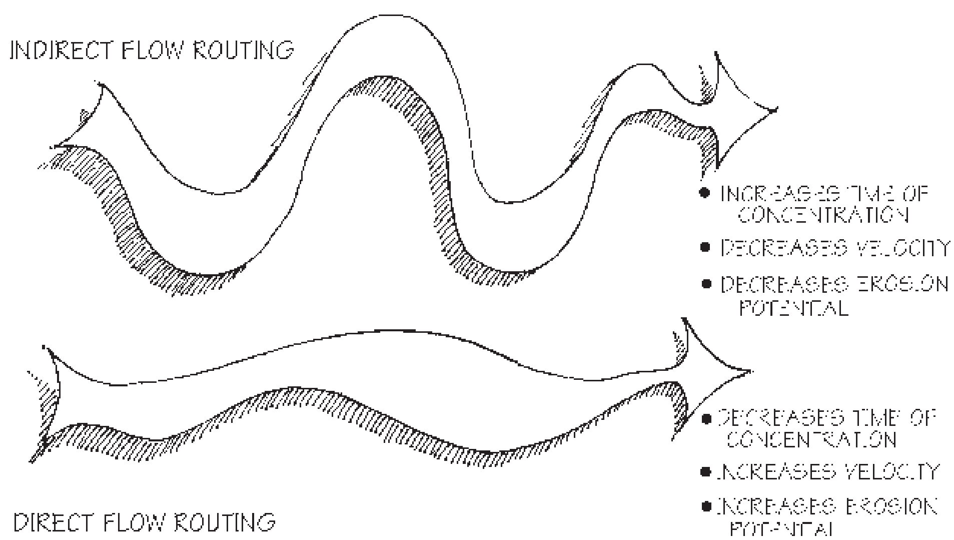
Components of the conceptual plan which are expected to generate stormwater runoff or will be a potential source of pollutants should be noted. As the conceptual plan elements are situated onto the base map and composite analysis drawings in order to fit them to the site, the stormwater management aspect of the plan can be considered and incorporated into the design.

Areas which will be covered by impervious surfaces, such as paving or rooftops, prevent runoff from being absorbed into the ground. Areas such as these can be expected to generate runoff. Portions of the site which are downstream or downhill from these areas can be expected to receive this runoff. Reducing the amount of impervious surface where possible will result in a reduction in runoff quantity.

The conceptual plan for stormwater management should generally show where stormwater runoff is being generated on the site and how it will be routed in order to control its quality before it enters surface waters. The actual methods used to transport runoff will include a combination of natural drainage features and man-made control measures. Examples of actual practices will be discussed in greater detail later in the manual.

Flow Routing

Routing of natural stormwater drainage can be shown with arrows. This routing can occur in the form of sheet flow or collected flow. Even at the conceptual level of design, an effort should be made to increase the distance over which stormwater flows so that pollutants and suspended materials are given a chance to settle out. *Indirect flow routing* will provide an opportunity to reduce time of concentration, provide for increased infiltration, and keep velocities lower so that the stormwater runoff will be less likely to carry suspended material to surface waters.



Stormwater Components of the Conceptual Plan

A completed conceptual site plan will show the sizes and shapes of plan elements located on the base map and will begin to show the details of the relationships between these elements. Buildings, parking, vehicular and pedestrian circulation, open areas, landscaped areas and other components of the development can be shown on this plan.

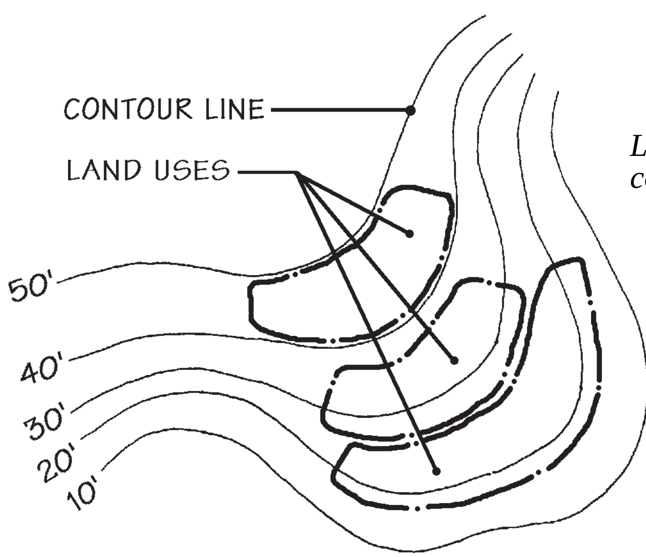
The conceptual plan is the most opportune part of the design process in which to use careful consideration and judgement in the siting of land uses so that the final plan will result in a cost effective and efficient stormwater runoff management system.

Guidelines to follow include:

- minimize disturbance to natural vegetation
- keep natural drainage patterns intact
- minimize use of impervious surfaces to promote infiltration
- route flow over longer distances
- keep runoff velocities low
- do not discharge runoff directly into surface waters
- use non-structural controls where possible
- use overland sheet flow
- maximize on-site runoff storage
- incorporate best management practices
- reduce impacts by clustering development

Follow Contours with land uses

Wherever possible, land uses should follow the contours of the site. Following contours with land uses, instead of crossing them will generally have many benefits. The uses will fit into the land more naturally and will require less grading. Since more of the natural earth is left intact, less natural vegetation will need to be disturbed. Also, the development will be more stable and less likely to erode if less area is disturbed.



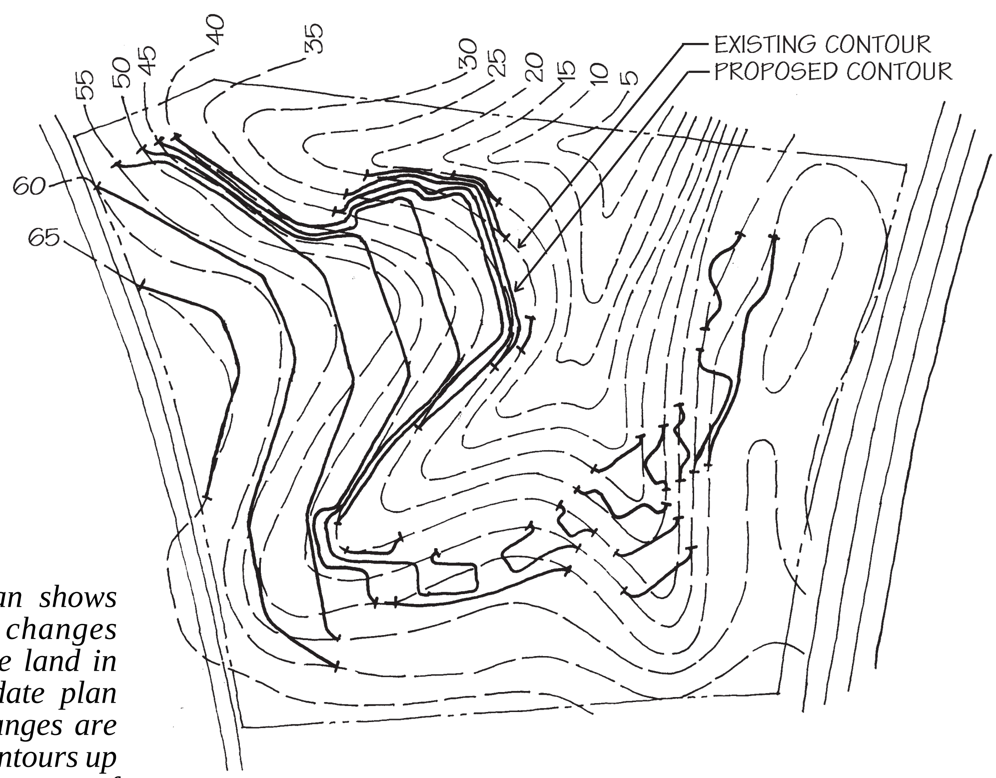
Land uses should follow contours to fit into the land.

From a stormwater design standpoint, fitting land uses to the contour of the land will help to prevent long, uninterrupted slopes. Longer slopes allow runoff to attain a higher velocity resulting in a greater ability to carry pollutants and sediment, increased erosive energy and a shorter time of concentration at lower elevations. Siting land uses to follow the contours slows runoff velocity and allows a greater opportunity for capture and infiltration.

Mass Grading Plan

Minimize grading by fitting elements to the natural land form.

A *mass grading plan* can be prepared for the conceptual site plan which shows where significant changes must be made to the land in order to accommodate plan elements. A mass grading plan is used to make design decisions at the conceptual level while plan elements are still being arranged on the plan. Since certain types of land uses such as buildings or parking will require level building sites, the land must be altered in these areas in order to be developed. The most suitable location on a site for this type of use can be identified first by noting the areas identified during the site analysis portion of the process. Also, it is important to note the location of existing drainage features so that they can be avoided wherever possible.



A mass grading plan shows where significant changes must be made to the land in order to accommodate plan elements. These changes are shown by moving contours up -slope to indicate an area of cut and down-slope to indicate areas of fill.

The mass grading plan is a useful tool for balancing the amount of soil which is cut with that which is filled. This is beneficial to the process because if the efficiency of grading can be improved, there will be a significant cost savings and less impact to the site.

Land use decisions and the selection of the measures which will be employed on the site for stormwater management should be resolved as much as possible at the conceptual plan level before proceeding to the more detailed Master Plan or Construction Documents.

The completed conceptual plan will generally show where stormwater runoff is being generated on the site and how it will be routed in order to control its quality before it enters surface waters. Land use decisions and the selection of the measures which will be employed on the site for stormwater management should be resolved as much as possible at the conceptual plan level before proceeding to the more detailed Master Plan or Construction Documents.

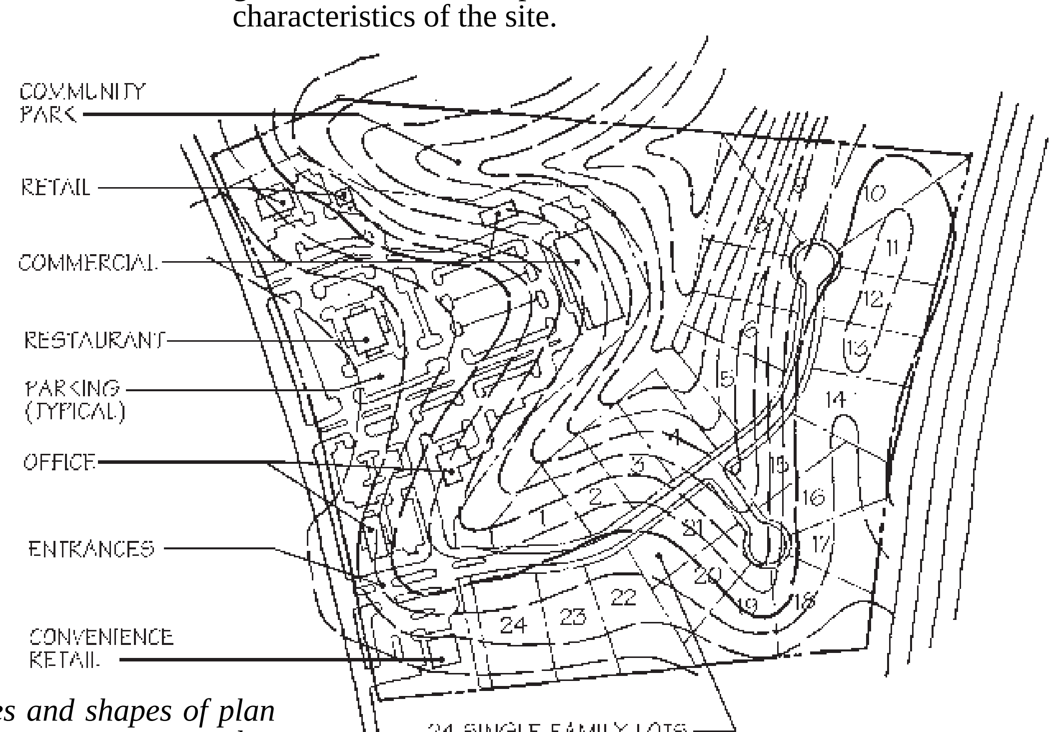
Master Plan

The Master Plan is typically drafted and precisely drawn so that it can serve as the basis for the preparation of Construction Documents.

The *Master Plan* for a development is a drawing which shows much greater detail than the Conceptual Plan - similar to the view as seen through an out of focus camera which is gradually brought into focus. The actual sizes and shapes of plan elements are shown at an accurate scale and the plan begins to look very realistic as though viewed from above. The Master Plan is typically drafted and precisely drawn so that it can serve as the basis for the preparation of *Construction Documents.*

Buildings on the Master Plan are shown to have the size and shape which they will have when built, parking lots are drawn to show placement of individual parking spaces, circulation routes are defined,and plan elements are shown in their final placement.

The preparation of a detailed Master Plan provides an excellent opportunity to integrate stormwater runoff management measures throughout the plan as an intentional part of the design. As facilities are situated on the Master Plan, thought should be given to their form and placement relative to the three dimensional characteristics of the site.



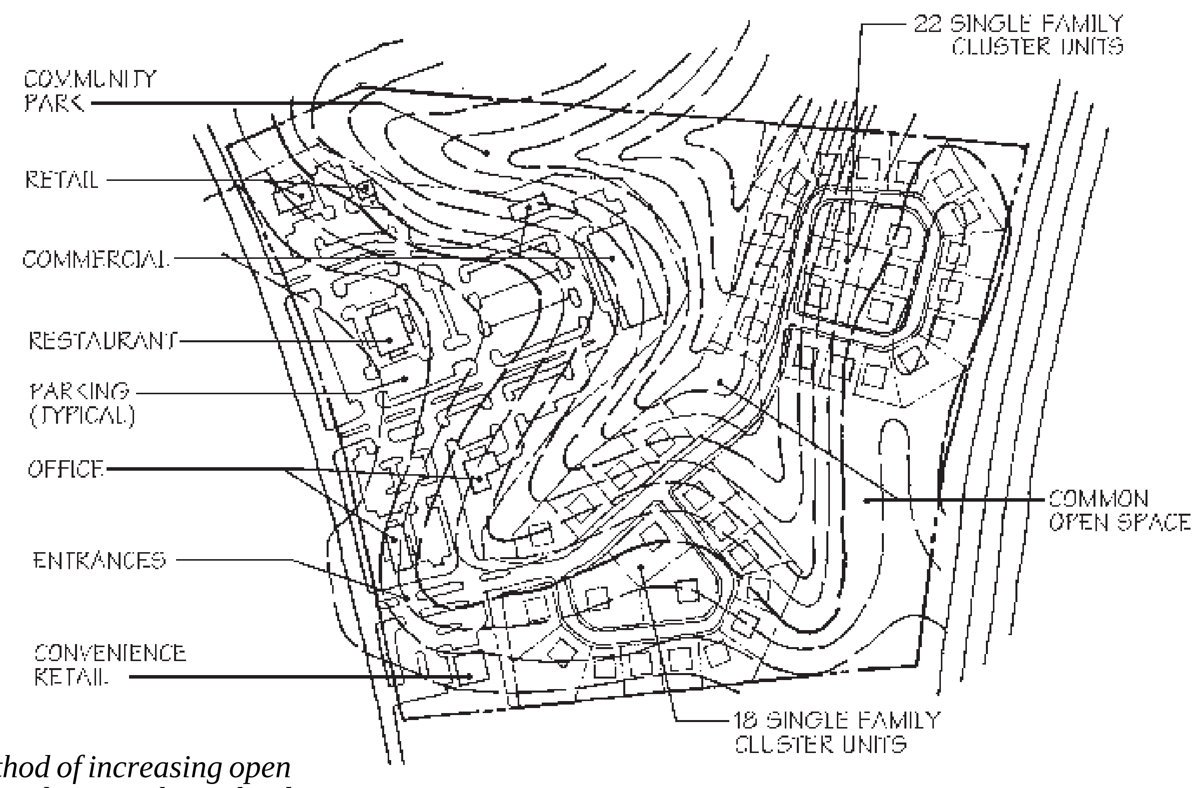
The actual sizes and shapes of plan elements are shown on a master plan at an accurate scale and the plan begins to look very realistic as though viewed from above.

Using only the amount of impervious surface necessary to accomplish the goals of program requirements and considering the significance of each plan component as a potential source of pollution will reduce the quantity of pollutants being generated.

Locating facilities away from surface waters and providing ample buffers and vegetative filters will help to control the quality of surface runoff entering waterways. Integrating stormwater management into the open space and landscape elements of a plan in a multiple-use manner improves the efficiency of the use of land on a site. These areas provide an opportunity to reduce impervious surface, provide areas for absorption of surface runoff and provide a means of slowing and filtering surface runoff near its source.

Integrating stormwater management into the open space and landscape elements of a plan in a multiple-use manner improves the efficiency of the use of land on a site.

Stormwater control measures can be integrated into the development plan when they are considered as an important land use component of the master plan. In order to reduce velocity and pollutant load, stormwater runoff generated by the impervious portions of the site should be routed through conveyances which will provide longer travel times, provide some means of filtering or capturing sediments and pollutants, and if possible allow for absorption of a portion of the runoff.

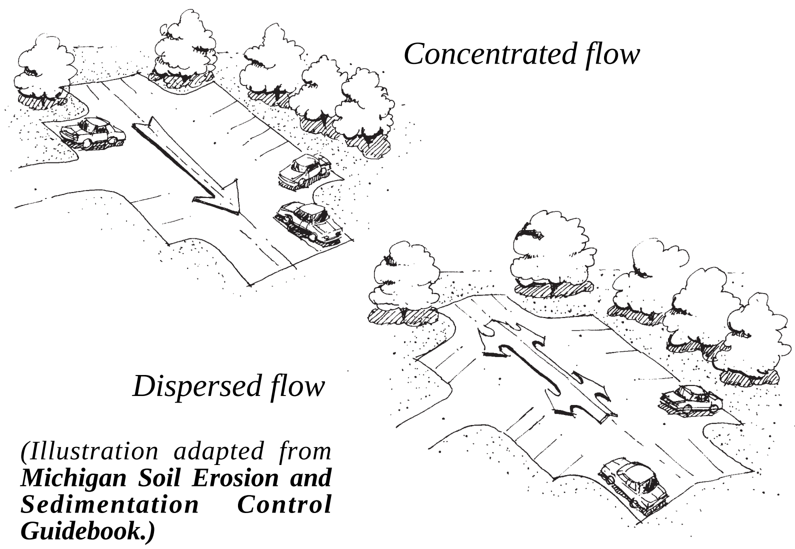


One method of increasing open space in a plan is to cluster land uses such as single family residential.

Many decisions can be made at the Master Plan level which will have an effect on the efficiency and cost effectiveness of the stormwater runoff management system. Since the detail of the Master Plan allows the more exact placement of elements onto the site, the stormwater management components of the plan should be shown in a more detailed manner on this drawing than on the Conceptual Plan. As details of various pavements and surfaces are shown, impervious area can be measured more accurately. Measurements can also be made to establish the sizes of various constructed components of the system. Sizes of individual components are based on the quantities of runoff which will be generated by each of the drainage basins of the site.

Calculations and formulas are used to determine the quantities and velocities of runoff which must be accommodated by each component of the stormwater system. These formulas are explained in great detail in engineering handbooks and are readily available for those who have a need or interest to use them.

The direction which flow is directed is one of the many decisions which can be made at the Master Plan level which will have an effect on the efficiency and cost effectiveness of the stormwater runoff management system.



(Illustration adapted from ***Michigan Soil Erosion and Sedimentation Control Guidebook.)***

Briefly, all components of a stormwater system must be designed to handle the runoff which will be generated by a storm with a known degree of intensity. This is known as a *design storm*. The design storm which must be used for the design of stormwater systems is typically specified for a given region or municipality in order to satisfy stormwater regulations. All components of the stormwater system must be able to carry the quantities and timing of rainfall which would result from the design storm. Additionally, the components of the system must be designed to withstand the forces of the flowing water and in some instances to retain a portion of the flow so that it can be released slowly.

The very specific and detailed design of each component of the overall stormwater management system will occur during the construction documents phase of the design process. It is important however, to understand the general requirements of the design so that any necessary modifications can be made to the overall plan as early in the process as possible.

Construction Documents

Construction Documents

In order to build a development from a Master Plan design, a more detailed and precisely engineered set of drawings, construction details and specifications will need to be prepared. These items are collectively known as the *construction documents* or CD's. A CD set of drawings will explain and describe in detail the dimensions, materials and construction methods which are to be employed in order to construct the project.

A typical set of construction documents will include:

- Site Survey
- Demolition and Clearing Plans
- Layout Plans
- Grading Plans
- Sediment & Erosion Control and Drainage Plans
- Architectural Plans
- Planting/Landscape Plans
- Construction Details
- Specifications

There are certainly less involved projects which will not require every one of the above listed items and other projects which are very large or complex which may require many more than are shown here. For an average site planning project, the necessary CD components will provide the information needed to construct the project as the designer intended.

Site Survey

The first layer, the *site survey*, is included in the set as a reference document. This drawing is the basis for all of the other construction documents since it records the legal limits of the parcel and other information about the site which is relevent to the development of the property. On many urban projects, there may be existing public stormwater systems or public drainage easements which are shown on the survey.

The site survey may be a *boundary survey* which is a drawing prepared to show the legal description of the property. A survey may also be a *topographic survey* which will show additional information about the site contours and will often show limits of existing vegetation and other physical features of the site such as buildings, fences, roads, etc. The survey may be the same base map that has been used throughout the previous steps in the process.

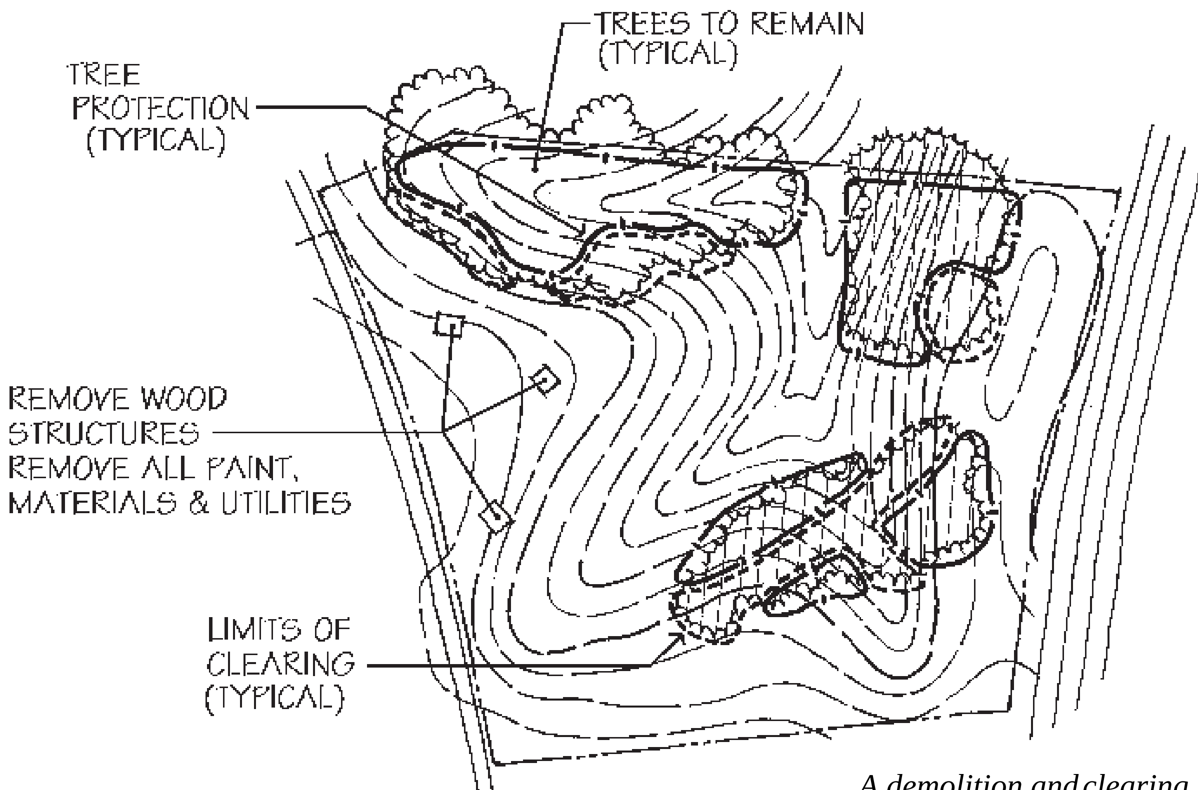
Demolition and Clearing Plan

The first drawing of the CD set which begins to show changes which will be made to the site is typically a *demolition and clearing plan.* This drawing indicates the portions of the existing site which are to be removed before construction can occur. Those items which will remain as a part of the development are noted "to remain"; other elements are shown to be removed.

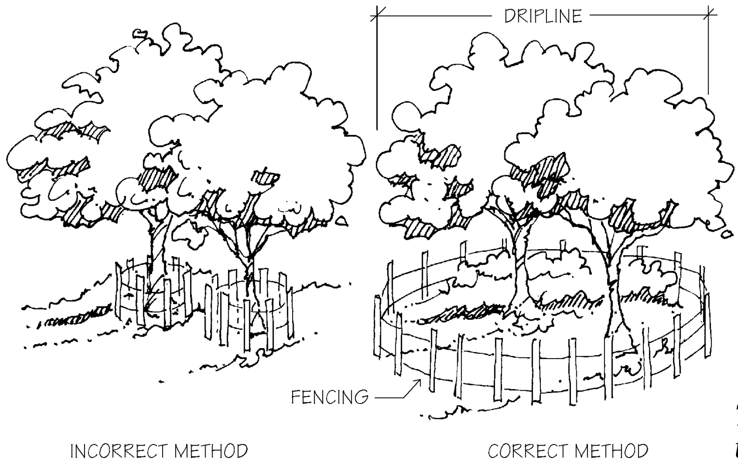
All vegetated areas of the site which are to be preserved should be clearly marked on the demolition plan so that appropriate tree protection measures can be taken before demolition of the site begins. This will avoid unintentional damage to the trees by equipment. Also, if areas are to be left in a natural state, they should be noted on the plan so that equipment is kept out of these areas in order to minimize damage and the need for restoration later.

The first drawing of the CD set which begins to show changes which will be made to the site is typically a demolition plan.

Areas which should be considered for protection include vegetated buffers to surface waters, natural drainage features, wetlands, floodplains, infiltration areas, steep slopes, and areas which have been designated on the master plan as undisturbed areas.



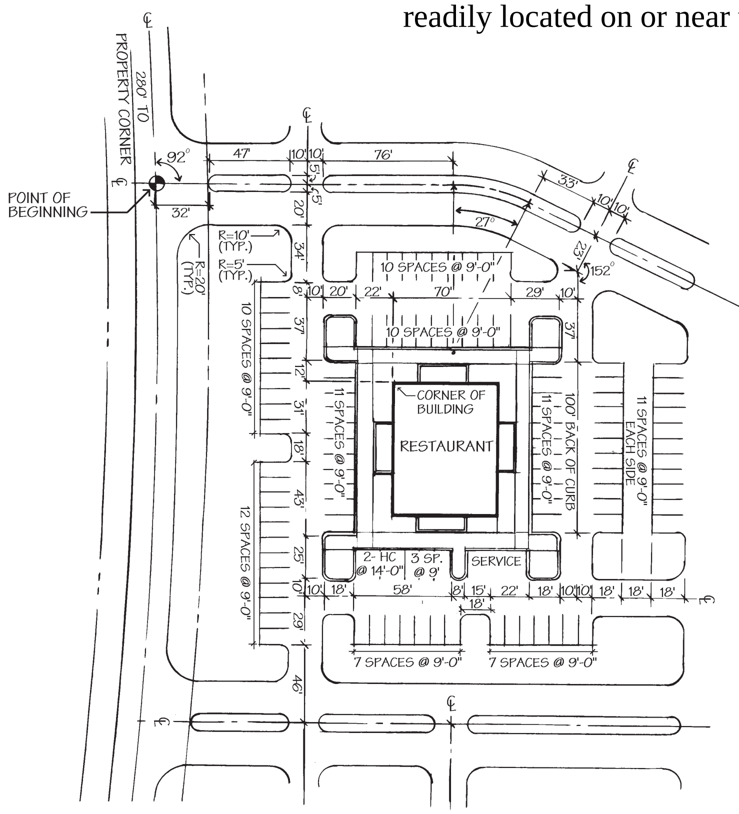
A demolition and clearing plan indicates the portions of the existing site which are to be removed before construction can occur. Those items which will remain as a part of the development are noted "to remain"; other elements are shown to be removed.



The correct method of tree protection should be specified on clearing or demolition plans.

Layout Plan

A *layout plan* is a measured and dimensioned drawing which describes how the various components of the Master Plan are to be surveyed and staked on the site. The layout plan establishes the two dimensional control of the arrangement of site plan components. This drawing is prepared by first establishing a *point of beginning.* As the name implies, a point of beginning establishes the point from which measurements and dimensions begin in order to lay out the design. This point can be a property corner, center of an intersection or any other point which can be readily located on or near the site.



A layout plan is a measured and dimensioned drawing which describes how the various components of the Master Plan are to be surveyed and staked on the site.

The most basic layout information locates road centerlines and building corners relative to the point of beginning. Each plan element is then located relative to the basic layout by dimension lines, angles and distances.

The layout of stormwater control measures should be conducted in the same manner as all other plan elements to ensure that they are incorporated into the plan and not afterthoughts. The layout plan should provide adequate space for each measure so that it will be able to function properly and allow access for operations and management.

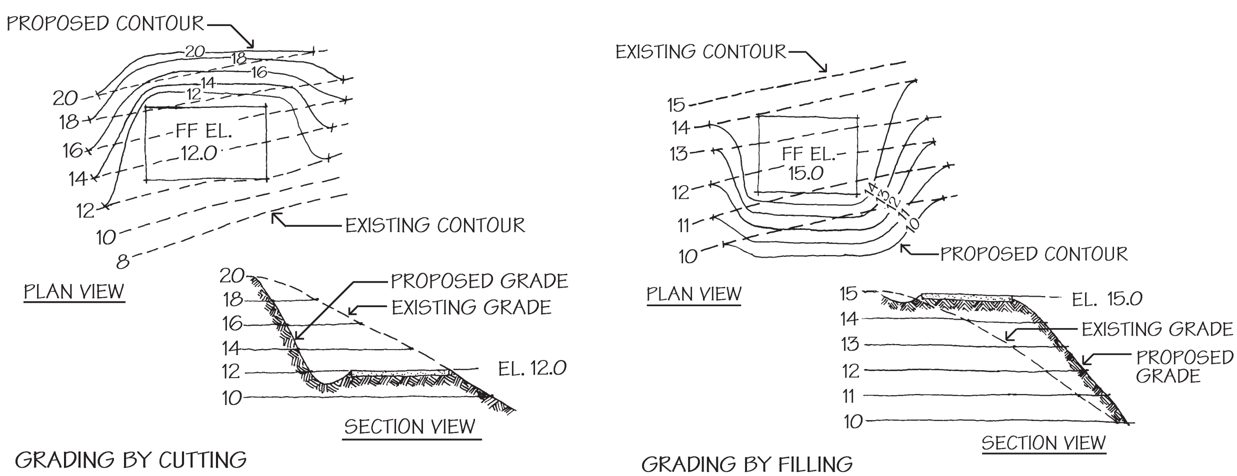
Grading and Drainage Plan

A *grading and drainage plan* describes and illustrates the changes which must be made to the contours of the site in order to accommodate the elements of the site plan. Level areas and sloped areas are created on the site by moving earth. These areas are created from existing grades by raising elevation (filling) - or by lowering elevations (cutting). These changes are shown on the grading plan by relocating the existing topographic contours so that they represent areas where the land will be cut and where it will be filled. The grading plan is really a form of three dimensional layout of the site plan.

Since the grading plan determines the changes to the grade of the site, this plan above all others will relate most closely to the stormwater runoff management of the development.

Since the grading plan determines the changes to the grade of the site, this plan above all others will relate most closely to the stormwater runoff management of the development. Grades which are established for each plan element will determine the direction, volume and velocity of the stormwater runoff being transported on the site.

Any changes in grade which are shown on the grading plan will result in a disturbance of the soil and any existing vegetation within the area to be changed. So if vegetation or natural drainage features are intended to remain intact, it is imperative that these areas be clearly noted on the grading plan and that the appropriate protection measures be installed in the field in order to prevent unintentional disturbances by grading equipment.



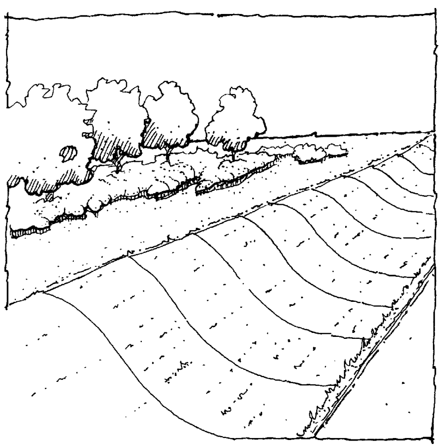
(Illustration adapted from Landphair, ***Landscape Architecture Construction)***

A grading plan depicts changes which will be made to the existing grade by cutting or filling.

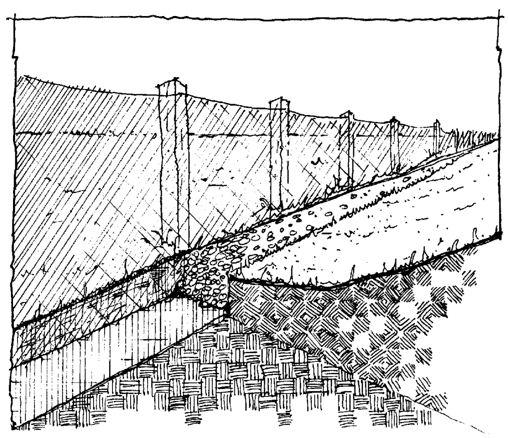
Sediment and Erosion Control Plans

Sediment and erosion control measures are required for most land disturbing activities in North Carolina. These measures are described in the *Erosion and Sediment Control Planning & Design Manual* as reviewed by the Land Quality section of NCDENR. For very minor activities, the measures are required to be installed on-site, but do not require an approved plan. All significant land disturbing activities, such as those associated with a development which disturbs more than one acre, require that a plan be prepared which shows the methods that will be used to prevent and control erosion and sediment pollution.

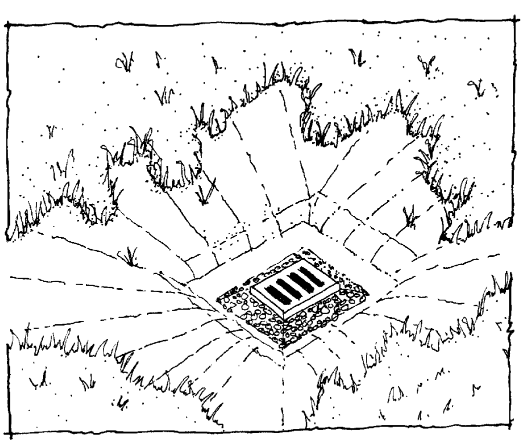
The methods which are employed to control erosion consist of stabilizing disturbed areas and preventing runoff velocities from eroding the soil surface. Sediment control measures are used to prevent soil particles and other solids from entering surface waters. Standard practices and methods of controlling erosion and sediment on a construction site include:



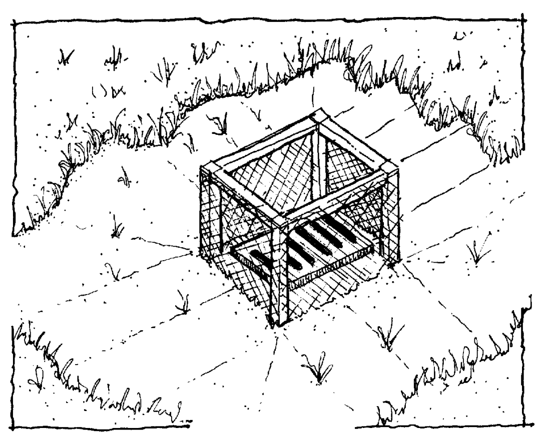
Slope stabilization



Sediment / silt fencing

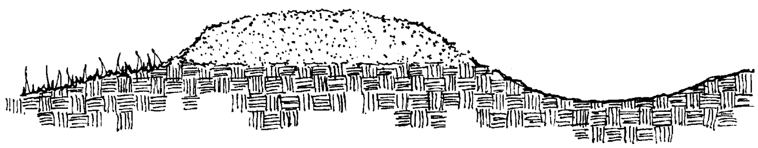


Depressional inlet protection



Fenced inlet protection

(Illustrations adapted from NCDENR, Land Quality, Erosion and Sediment Control Planning & Design Manual)



Temporary diversion ditching

Sediment basins

(Illustrations adapted from NCDENR, Land Quality, Erosion and Sediment Control Planning & Design Manual)

There is much similarity between the goals of a sediment and erosion control plan and those of a stormwater runoff management plan.

There is much similarity between the goals of a sediment and erosion control plan and those of a stormwater runoff management plan. The purpose of both is to control runoff and pollutants and to prevent degradation of surface waters. Erosion control methods are similar to the prevention and source reduction aspect of stormwater management. The control of sediment is similar to the control of pollutants in runoff and employs similar methods.

A well designed sediment and erosion control plan utilizes existing grades and surface flow patterns to the greatest extent possible. A stormwater management plan which is closely related will be able to take advantage of the surface flow patterns and control measures already in place on a development site. Considering a permanant stormwater runoff management strategy during the design and implementation of the temporary sediment and erosion control plan will reduce grading costs and will allow an existing functioning system to be upgraded instead of a duplication of effort in creating a new system. Also, using areas which have already been disturbed will allow a greater amount of the site to be left in its natural state.

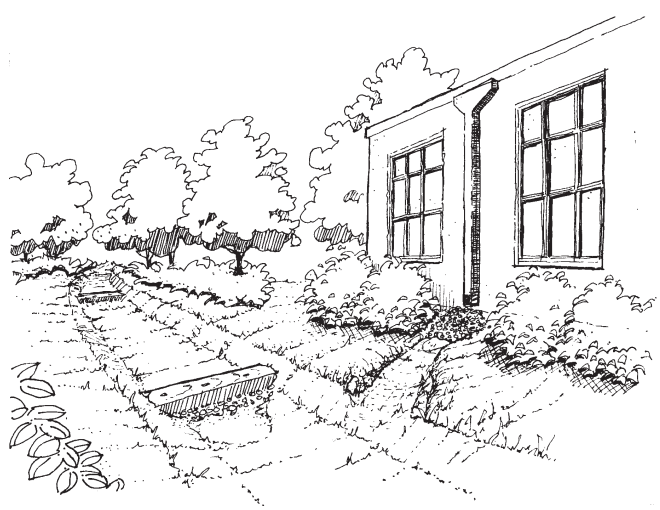
In order to design a sediment and erosion control plan to be used as part of a permanent stormwater management plan, there will need to be allowances made for the additional runoff which will be generated by new impervious surfaces. Additional space should be provided in the plan to allow for more extensive permanent controls and best management practices (BMP's) than may be required for sediment and erosion control. Also, the measures used in the sediment and erosion control plan should protect and preserve the integrity of vegetated infiltration areas, natural drainage systems and newly constructed surface conveyances which will be a part of the permanent system.

Architectural Plans

The *architectural plans* show the detail design of buildings and other architectural elements of the site plan. The buildings and their associated exterior paved surfaces and parking account for the majority of the impervious surface found on a typical plan for development. Since these areas are the source of the majority of new runoff which is generated on a site, they offer the greatest opportunity to reduce the quantity of runoff through design modifications. The design of buildings can be modified to generate less runoff through a variety of means.

- Decrease the size of buildings and minimize rooftop surfaces through more efficient use of space.
- Design the building in a manner which requires less disturbance of land.
- Allow a greater amount of natural vegetation to remain undisturbed so that infiltration rates will be greater.
- Direct the flow from downspouts into vegetated areas or subterranean areas instead of into a stormwater collection system. This can greatly reduce the overall runoff generated by the site.
- If there is a need for landscape irrigation, the runoff generated by building rooftops is generally clean and can be temporarily stored and re-used as a source of water.

Paved areas which surround buildings such as decks and patios will generate runoff which can also be reduced by modification of design or materials. As in the design of interior spaces, exterior areas can be designed to make more efficient use of space; a smaller well-designed area might function as well as a larger poorly designed area. The materials which are selected for these areas can reduce the amount of the area which is impervious. Some materials such as wood decking are more porous than others and will allow a greater amount of rainfall to infiltrate.



Directing the flow from downspouts into vegetated areas or grassed swales can greatly reduce the overall runoff generated by the site.

Graphic of downspout flow into vegetation

Also, the runoff from decks or patios can be directed into landscaped or natural areas instead of into a stormwater system. The best approach to directing runoff from these exterior surfaces which do not tend to generate a lot of pollutants is by sheet flow.

Planting Plans / Landscape Plans

Most types of development will have some form of landscape treatment. The drawings which are used to illustrate and explain the landscape design consist of three components.

Landscape plans illustrate the arrangement of planted areas, natural areas, exterior pavements, exterior landscape structures, lighting, irrigation and other landscape features onto the site plan. The *landscape construction details* explain and illustrate information necessary to construct the elements shown on the plan drawings. *Landscape specifications* provide descriptions and standards for the methods and materials which are to be used in the construction.

Landscape techniques can be used which will reduce the quantity of runoff generated by the site and improve its quality.

Stormwater runoff management will be affected in at least two ways by the landscape design. First, the amount of area which is left undisturbed as natural area will provide an opportunity for infiltration and will have lower maintenance requirements than areas which are intensively landscaped. Second, the landscape techniques, plants and materials which are selected for use in landscaped areas will have maintenance requirements which can influence both the quality and quantity of stormwater runoff.

The use of indigenous grass or herb species in the remaining lawn area will require less irrigation or chemical support for survival. The challenge of this approach is to select a palette of native plants which will satisfy the need for quality runoff without offending the suburban aesthetic of manicured neatness.

Most plants selected for urban or suburban landscapes are selected because they are plentiful and inexpensive. Little consideration is given to the adaptability or maintenance needs of the plants. The use of resource efficient plants in a landscape design can greatly reduce the need for excessive amounts of fertilizers, chemical pesticides, or irrigation which is needed in order to keep them vigorous.

Landscape planting plans are typically comprised of two parts; first, the selection of plant species or surface materials to be used, and second, their location and placement within the site design. If some thought is given to stormwater when the decisions on the landscape plans are being designed, this portion of the site plan can make a significant contribution to the overall quality of runoff.

The use of resource efficient landscape design techniques will help to prevent urban non-point source pollution. A successful resource efficient landscape design begins with an understanding of the site which is to be designed and the resources to be protected.

A successful resource efficient landscape design begins with an understanding of the site which is to be designed and the resources to be protected.

- Work with the natural hydrology of the site instead of altering it.
- Use buffer zones to protect surface waters.
- Limit impervious area where possible
- Manage runoff and pollution from impervious areas close to the source
- Select resource efficient plants adapted to the area.
- Replace large areas of high maintenance landscape with adapted or native plants
- Group plants according to similar growing and resource requirements
- Match landscape plant groupings with appropriate existing site conditions.
- Manage water use and irrigation efficiently
- Use mulch where possible
- Manage nutrients wisely
- Increase mowing height of lawn areas
- Use composting of lawn waste to recycle nutrients
- Use natural and vegetative areas for stormwater management
- Use captured runoff for irrigation

Single family lots and some other types of development are comprised primarily of lawn. While these areas are not impervious, they can contribute significantly to the pollutant load in stormwater runoff. The typical subdivision lawn is comprised of non-native grass species which require large amounts of fertilizer in order to grow lush and green. Additionally, the non-native species of grass in most lawns are subject to a variety of pests and diseases which are controlled with potentially toxic chemicals. Many lawn areas are also irrigated which, if excessive, can contribute to runoff volume by keeping soil pores saturated.

Runoff quality from single family lots and other similar land uses can be improved by reducing the amount of lawn area of the lot and replacing it with mulched beds or natural areas as well as better management of fertilizer and chemicals.

Irrigation plans

Irrigation products are available which minimize the amount of water necessary for landscape plant growth by distributing it more efficiently. These products include drip irrigation methods and low flow heads. By reducing the amount of water which could be potentially contributed to runoff from over-spray or excess, these products help to reduce the overall impact of stormwater originating from landscaped areas and surrounding pavements. One irrigation product which has greatly improved the efficiency of an irrigation system is the central computerized controller which is programmed to respond to soil moisture sensors, climatic conditions, evapotranspiration rates, as well as to provide the specific amount of water required for a particular zone depending upon the type of plants being grown and their specific water demands. The more efficient use of water for irrigation means that less water is wasted and the soil in landscaped areas is not continually saturated. The result is that any precipitation that falls is more likely to infiltrate the soil than leave the area as runoff. Under ideal conditions, if the quality of runoff can be controlled to the degree that it can be captured and utilized as a source of water for irrigation, there would be even less runoff generated by a site. Care must be taken to allow for the removal of sediment and pollutants from runoff before it is collected and stored for such use. Their removal will prevent possible damage to irrigation systems and the accumulation of pollutants in areas where they cannot be periodically removed.

Runoff from areas which are relatively pollutant free can be used to reduce the need to irrigate if it can be directed into landscaped areas in a controlled manner. Care must be taken in the design of a system such as this to ensure that a landscaped area will receive enough water that the plants flourish but not so much that problems are caused by overwatering. This problem can be overcome in part by selecting landscape plants which are adapted to the amount of water which an area is expected to receive.

Construction Details

The *construction details* are the portion of the CD set which provide examples and illustrations of the detailed construction of plan components. Typically shown in the construction details are explanations of how various components of the master plan are to be constructed or implemented. These drawings also provide the opportunity to show portions of the Master Plan at a larger scale which allows more information to be shown.

Best Management Practices

Construction details of Best Management Practices (BMP) which will be used as stormwater control measures throughout the site plan should be included in the details section of the CD set to ensure that they are constructed properly and that they will function as intended when built.

There are a wide variety of BMP's which can be incorporated into a plan. BMP's are also known as control measures, or constructed devices which control runoff quantity and quality. Where control measures or BMP's become necessary, as a supplement to preventive and source reduction practices, the use of a combination of smaller controls to capture or treat runoff should be designed as integral parts of the overall site plan, not as separate elements. BMP's can be grouped into the following general categories:

General BMP Categories

• Conveyance devices
  - Curb Openings
  - Grassed Swales

• Storage devices
  - Wet Detention Ponds
  - Dry Detention Ponds
  - Extended Stormwater Wetlands
  - Pocket Wetlands
  - Bioretention areas

• Filters and Traps
  - Filter Strips
  - Sand Filters
  - Oil and grease traps

• Infiltration devices
  - Infiltration trenches
  - Infiltration basins

Categories of control measures are related to size, position in the landscape and function within the overall stormwater system. There have been numerous studies conducted on the effectiveness of various measures and the details of design and use. As mentioned in Section 1, the Division of Water Quality (DWQ) has prepared a document entitled "Stormwater Best Management Practices" November 1995, which describes the use and effectiveness of various types of measures and should be referenced for a detailed background explanation.

Conveyance devices

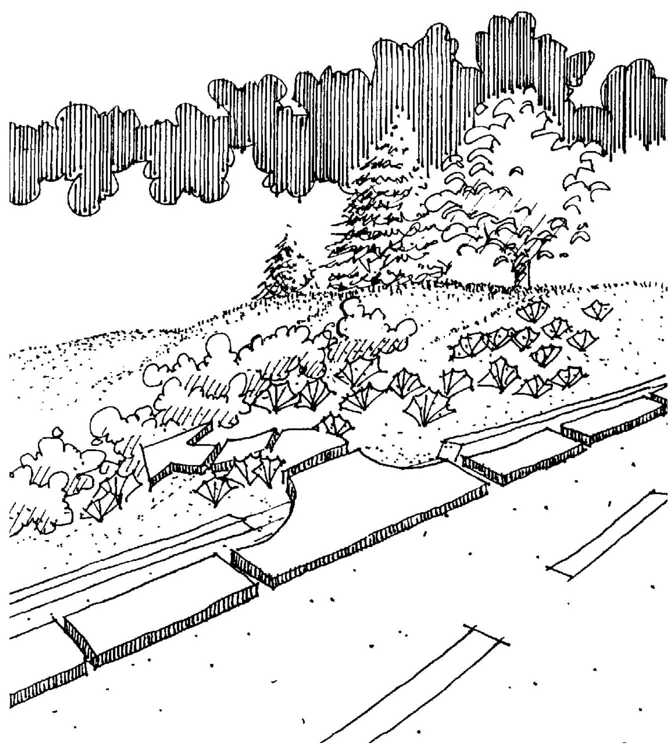
Stormwater runoff is usually collected and transported by a series of catch basins, pipes and ditches. While these methods are very efficient in moving large quantities of runoff rapidly away from a site, they offer little in the way of pollutant removal. Using more natural engineering methods, also known as bioengineering, in order to collect and transport runoff offers the benefit of improvements to runoff quality.

Curb openings

In developments which have curbs, *curb openings* can serve a purpose comparable to a catch basin. By providing an outlet into adjacent vegetated areas, natural areas or swales an opening in a curb will disperse collected flows and provide an opportunity for treatment or infiltration. Curb openings should be situated at low points along the roadway or if the road surface is crowned, curb openings can be placed part of the way down a side slope.

Where space allows, curb openings should be as wide as possible to keep velocities slow and shallow. A narrower opening will tend to concentrate the flow and may cause erosion at the point where runoff leaves the pavement.

Openings in curbs can be included in the design of new developments as well as in existing development situations. Before providing the opening, however, it is important to know where the runoff will go once it passes through the curb. Areas should be identified or designed as a part of the overall system which will be able to accommodate storm flows without causing damage to property or creating other problems. It is best if curb openings can be used in conjunction with other natural engineering measures in order to provide a means of controlling the runoff once it leaves the pavement.



An opening in a curb will disperse collected flows and provide an opportunity for treatment or infiltration

(Illustrations adapted from NCDENR, Water Quality, Stormwater Management Guidance Manual and BMP's)

Grassed swale

The use of *grassed swales* instead of pipes or lined ditches will allow runoff to be slowed and filtered as it is transported. An additional measure of control can be provided with check dams placed across the width of grassed swales. The check dams can be made of landscape timbers, rock or stabilized earth. The use of waterbreaks will slow runoff, capture pollutants and allow infiltration without impeding the extreme flows generated by large storms.

Where it is possible, a more natural design of grassed swales is preferable to a straight sided engineered design. A curving swale of varying width will fit into the landscape more naturally and will provide a longer path of runoff flow.

Although grassed swales can be of many different designs, a broader design will be most effective for pollutant removal. Where space allows, a broader swale should be used to keep velocities low and to prevent erosion from occurring. A narrower cross section will encourage faster and deeper flow, is not as effective for pollutant removal, and may result in erosion if vegetation is not properly established and maintained. If a narrower channel is used, check dams and taller grasses with deeper root systems can help to control channel erosion.

A grassed swale with check dams will carry surface flow, slow the rate of runoff and provide filtering of pollutants.

(Illustrations adapted from NCDENR, Water Quality, Stormwater Management Guidance Manual and BMP's)

Storage devices

These devices are intended to withhold runoff for a period of time and to release it more slowly back into the surface water system.

Storage devices include various retention and detention structures which are similar in design and function. The design of each measure will usually include a berm or embankment at the lower end to capture runoff, a storage basin behind the berm and some means of controlling the outflow of runoff. Additional features might be included in the design which are related to the function of the device such as forebays or low flow channels.

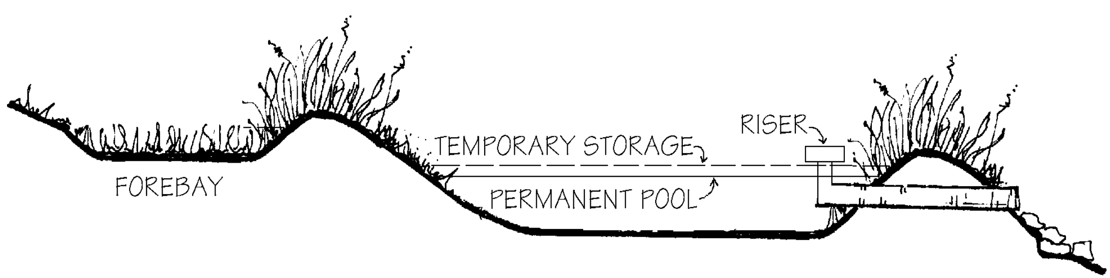
Some common storage devices include: wet detention ponds (wet ponds), dry detention ponds, extended stormwater wetlands, pocket wetlands and bioretention areas. These devices are intended to withhold runoff for a period of time and to release it slowly back into the surface water system. During the time that runoff is being held - also known as *residence time*- pollutants and sediments are given opportunity to settle out or to be filtered by vegetation.

Wet detention pond

A *wet pond* or *wet detention pond* is the most common of the storage devices and is usually the type of BMP which is recommended or required because of its effectiveness as a control measure for both runoff quality and runoff quantity. A wet pond is designed to have a permanent pool of water between rainfall events (permanent water quality pool).

In addition to the permanent pool there is room for temporary storage of storm flows which are held for a time then released. The mechanism used for controlling the rate at which stormwater is released may be in the form of a weir, standpipe or other overflow device. There are many designs for water control devices, all of which serve the same basic purpose.

Another component of most wet ponds is a *forebay*. A forebay is a small basin located upstream of the main storage basin which collects sediments before they enter the larger basin. The forebay is designed to be accessible so that it can periodically be cleaned out. The use of a forebay in the design of a wet pond can greatly improve the water quality of the main basin. This is especially helpful for ponds which are intended to be used for purposes such as amenity, recreation or wildlife habitat.



A wet detention pond can provide some of the most efficient pollutant removal, especially if a forebay is included in the design.

(Illustrations adapted from NCDENR, Water Quality, Stormwater Management Guidance Manual and BMP's)

Dry detention pond

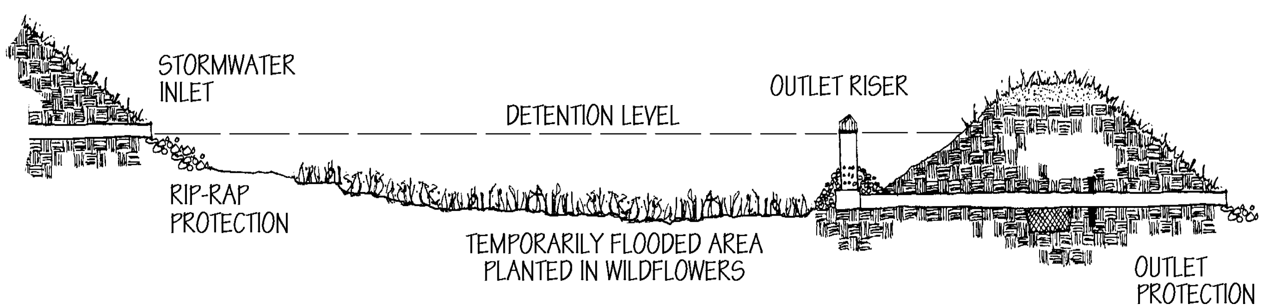
A *dry detention pond* - or dry pond - is very similar to a wet pond except that it does not have a permanent pool of water. The dry pond is a basin which accepts and detains storm runoff so that it can be released slowly. The pond then remains dry between storms. The effectiveness of a dry pond in pollutant removal is not as great as that of a wet pond. However, since there is no permanent pool to maintain, construction and maintenance costs may be significantly less.

Dry ponds have been used for many years to control runoff quantity from peak flows. More recently, a modified design of a dry pond, the *extended dry detention basin*, has been used as a water quality BMP. The extended dry detention basin provides a longer detention time for smaller storms than a normal dry pond and allows a greater amount of sediment and pollutant to settle out.

A dry pond has certain advantages over a wet pond. It is not as limited by terrain or soils since there is no permanent pool to maintain. A dry pond can be of almost any size and can be worked into a site plan as part of the open space. If a dry pond is large enough it can provide valuable wildlife habitat which benefits from the concentration of water. The bottom of a shallow dry pond basin can be planted in wildflowers. Since there is no permanent pool of water, there is less chance of the area becoming an attractive nuisance to children.

There are also disadvantages to using a dry pond. Unless they are well designed and maintained properly, an accumulation of sediment and trash can make these areas very unattractive. Also, depending on the source of runoff, many people may find odors from dry pond areas objectionable.

Dry ponds are most effective for pollutant removal when they are used in combination with other measures such as grassed swales.



A dry detention pond can provide pollutant removal as well as reduce the quantity of runoff which leaves a site.

(Illustrations adapted from NCDENR, Water Quality, Stormwater Management Guidance Manual and BMP's)

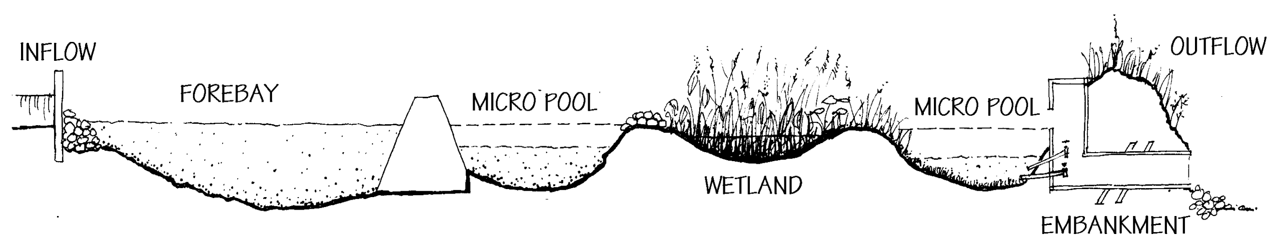
Extended Stormwater Wetlands

Stormwater wetlands are very similar in design to wet ponds and dry ponds. They occur between the two in terms of permanent wetness of the basin area. While a wet pond has a permanent pool, and a dry pond is designed to be dry between storms, a stormwater wetland is intended to remain wet enough to encourage the growth of wetland plant species within the basin. The wetland plantings offer the benefit of slowing flow, providing nutrient uptake from runoff and capturing sediments. Small pools of water called *micropools* are provided within the basin for settling and slowing water velocities; the depths of these pools are typically less than three feet.

As in the design of a wet pond, a forebay is included upstream of an extended stormwater wetland in order to provide early sediment removal.

Pocket wetlands

Pocket wetlands are similar in design to extended stormwater wetlands, but on a smaller scale. Pocket wetlands are intended to serve smaller sites or portions of drainage basins. The features of a pocket wetland are the same as those of a larger stormwater wetland except that the micropools do not need to be as large and a forebay is not usually a requirement due to the much smaller contributing drainage area.



Artificial stormwater wetlands can remove pollutants, provide animal habitat and provide landscape value.

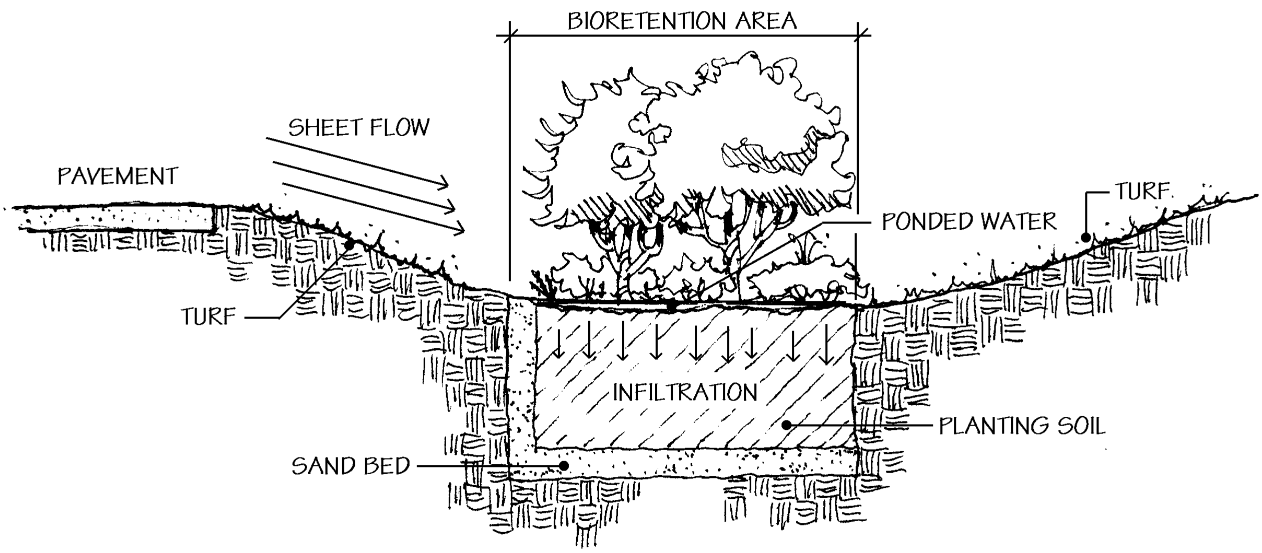
(Illustrations adapted from NCDENR, Water Quality, Stormwater Management Guidance Manual and BMP's)

Bioretention areas

Bioretention areas have characteristics in common with other storage devices in that they provide a temporary storage volume and a means of treating and slowly releasing runoff; however, they differ in the mechanism which is used to treat the runoff once it is captured. Water exits the bioretention area by infiltration into the ground or by evapotranspiration through the plants.

These areas utilize a combination of a grass filter strip, ponding area, sand bed, planting soil, organic layer, and plant material to re-create the filtering and absorption found in a more natural forest-type setting. This is accomplished by directing runoff into a depressional planted area which provides temporary storage, infiltration, plant uptake and evapotranspiration.

Each component of the bioretention area serves a function in the overall effectiveness of the area for pollutant removal.



Bioretention areas utilize a combination of a grass filter strip, ponding area, sand bed, planting soil, organic layer, and plant material to re-create the filtering and absorption found in a more natural forest-type setting.

(Illustrations adapted from NCDENR, Water Quality, Stormwater Management Guidance Manual and BMP's)

Filters and Traps

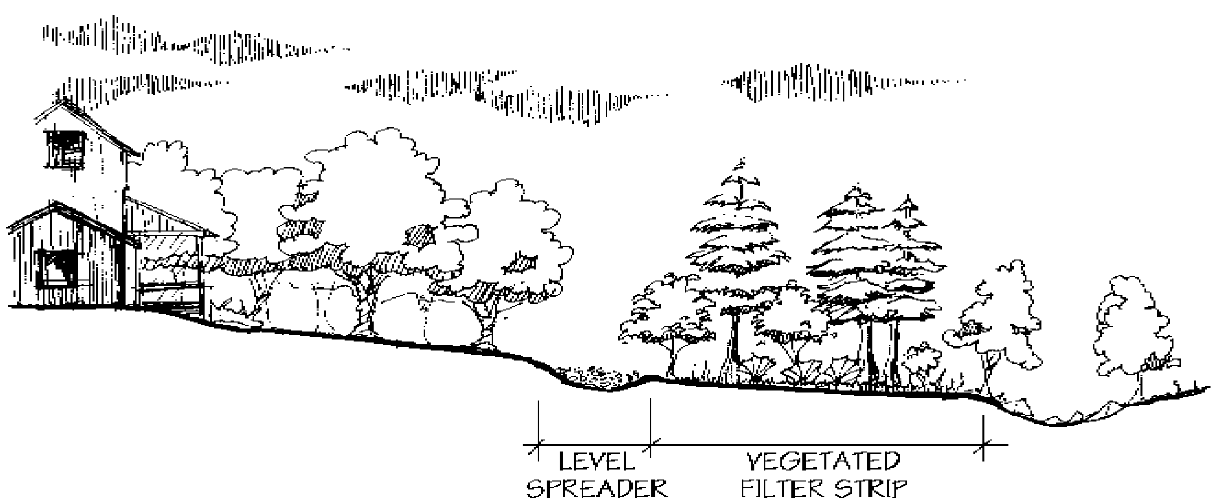
The category of constructed BMP's which are designed to mechanically trap or filter sediments and particulate material from runoff includes filter strips, sand filters, and oil/grease traps. Each of these measures is incorporated "in-line" as part of a stormwater management system which means that stormwater is intended to pass through these devices. Each device is designed to capture runoff and to remove suspended material from the runoff before it is released back into the system.

Filter Strips (Vegetated)

Filter strips are bands of vegetation through which stormwater runoff can be routed in order to reduce pollutants and slow velocity. These devices are level areas situated between upstream development and surface waters which have been planted or left natural in close-growing grasses or dense woody plants. Runoff from the development is directed into a filter strip, spread out and strained through the vegetation thereby removing sediments and pollutants.

A level spreader along the upstream side of a filter strip will help to reduce velocity of runoff as it enters the strip by spreading the runoff into a thin layer before it enters the vegetation. This will aid in pollutant removal and will help to prevent channelization within the filter strip. A level spreader can be in the form of a stone filled trench. The level spreader will slow the runoff and spread it out before it enters the vegetative filter strip.

Filter strips are not as effective at pollutant removal as some of the more structural types of controls, such as wet ponds, and function best when used in combination with other BMP's in areas which have lower density development. If not well maintained, the vegetated filter strips can become channelized or the vegetation may become thin and pollutant removal capability diminished.



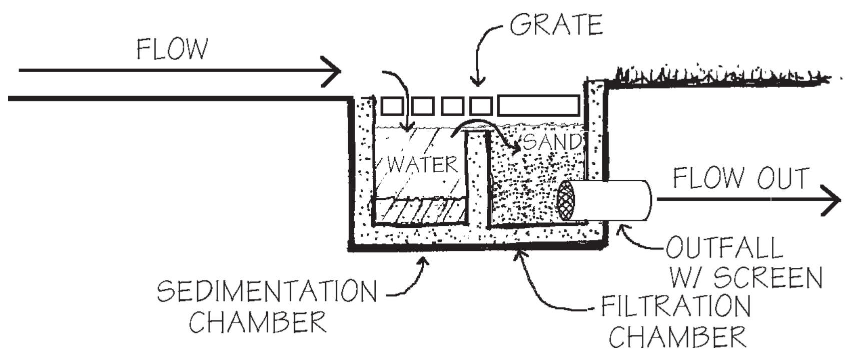
A vegetated filter strip provides a buffer between development and surface waters. The vegetation traps and filters pollutants while slowing flow velocity.

(Illustrations adapted from NCDENR, Water Quality, Stormwater Management Guidance Manual and BMP's)

Sand Filters

A *sand filter* is basically designed as a box filled with sand. Runoff which is directed into one side of the device is filtered as it passes through sand before being released. The box is designed in such a way that runoff from an impervious area - such as a parking lot - is directed by sheet flow into a grate. The grate is situated over an empty chamber (sedimentation chamber) which receives the runoff and allows a settling of heavy sediments and debris. The runoff fills the sediment chamber and overflows into another chamber which is filled with sand. Since the openings between sand particles are very small, finer sediment particles are trapped as the runoff passes through. Once the runoff has passed through the sand filled chamber, it is released from the device and back into the stormwater system.

One advantage of a sand filter is that it can be easily cleaned out so that accumulated sediments and debris are not allowed to be re-suspended, preventing them from entering surface waters. Another advantage is that these filters require relatively little room and can be incorporated into paved areas or other areas where space is limited. A major disadvantage is that sand filters require regular maintenance in order to remain effective.



A sand filter consists of chambers which allow sediment to settle and pollutant bearing particles to be removed from runoff.

(Illustrations adapted from NCDENR, Water Quality, Stormwater Management Guidance Manual and BMP's)

Infiltration Devices

Infiltration of stormwater returns rainfall directly to the soil without allowing it to become runoff. This prevents the stormwater from entering surface water systems and retains it on the site. In order to allow sufficient time for the soil to absorb the runoff, an infiltration device is designed to capture and hold runoff, releasing it back into the ground.

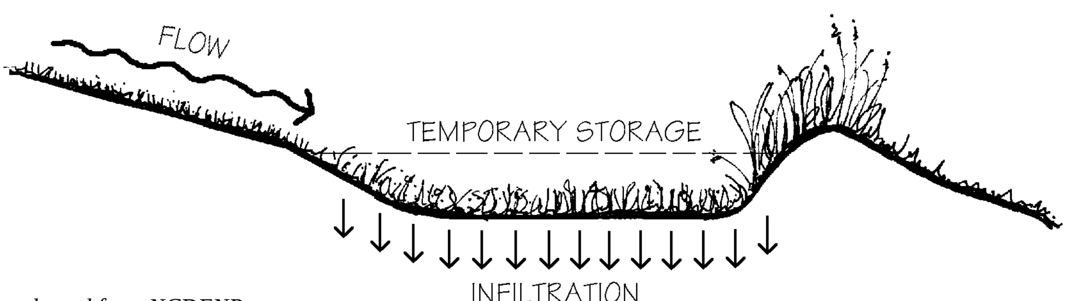
The sources of runoff which are best suited to infiltration devices are those which are relatively free of pollutants such as runoff from rooftops and sidewalks.

Three designs of infiltration devices all perform the same function but differ significantly in size and shape. Large infiltration areas are called *infiltration basins;* smaller elongated basins are known as *infiltration trenches;* and smaller compact devices are called *dry wells.* This variety in design allows for use in many different situations throughout a site plan depending upon the size of the area to be served and the source of the runoff.

The source of runoff is an important consideration when deciding to use any type of infiltration device. They can easily become clogged with debris or sediment and cease to function if these materials are present in the runoff which enters them. The sources of runoff which are best suited to infiltration devices are those which are relatively free of pollutants such as runoff from rooftops and sidewalks.

Infiltration basins

Infiltration basins are similar in design to a dry pond except that they do not have an outlet into a surface water. These basins are only useful if they can be sited in permeable soils which will allow all of the runoff entering the basin to be absorbed following a storm. These basins are well suited for use in large open areas and can be of nearly any shape. If well drained, these areas can serve other purposes during dry weather.



(Illustrations adapted from NCDENR, Water Quality, Stormwater Management Guidance Manual and BMP's)

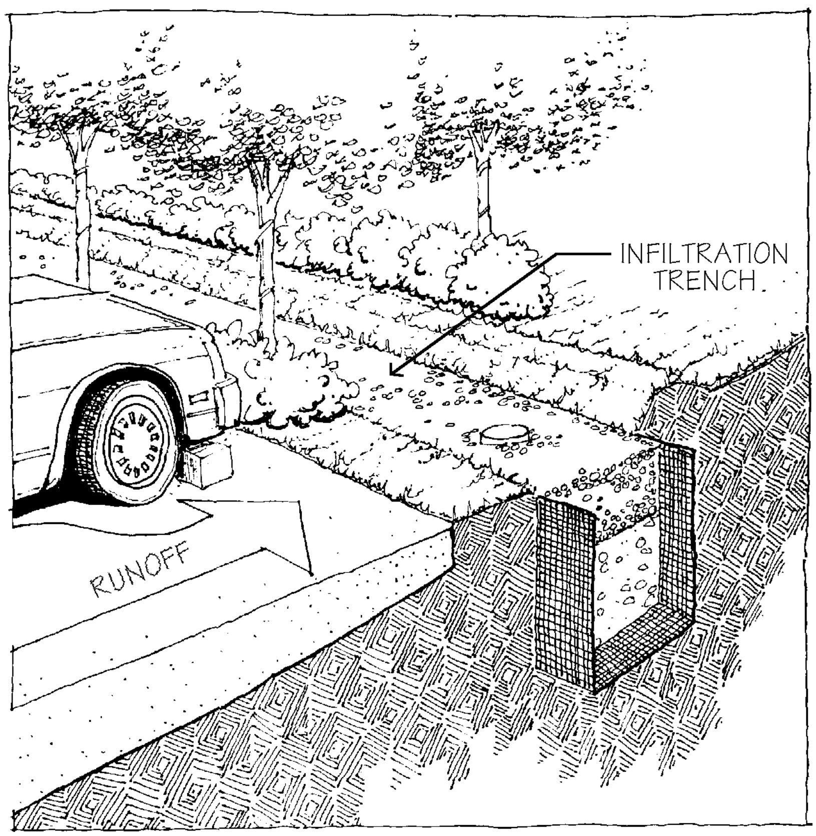
Infiltration basins are similar in design to a dry pond except that they do not have an outlet into a surface water.

Infiltration trenches

Infiltration trenches are much smaller and more elongated than basins and are usually used to capture the runoff from buildings and from parking lots. An infiltration trench can be situated along the side of a parking lot to receive sheet flow or in open areas along buildings to receive flow from rooftops. The advantage of an infiltration trench is its narrow size which can easily be incorporated into a site plan without taking up much space.

Infiltration trenches can be dug into the ground and filled with crushed rock, or they may be trenches made of cast concrete which provide volume for runoff storage until it can be absorbed by the soil through openings in the trench wall.

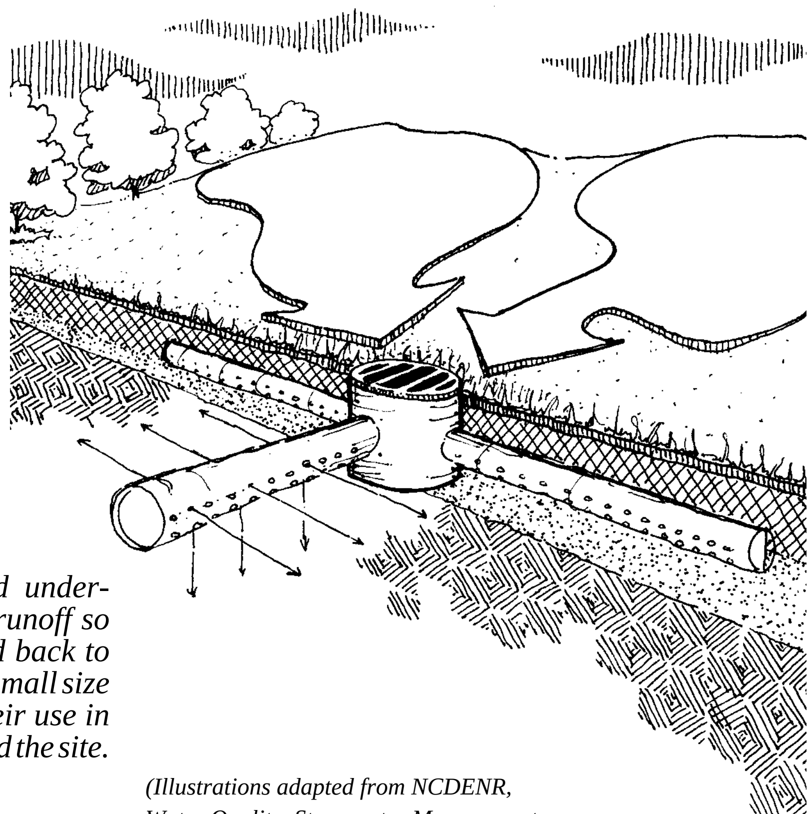
An infiltration trench can be a useful control measure in confined urban settings



(Illustrations adapted from NCDENR, Water Quality, Stormwater Management Guidance Manual and BMP's)

Dry wells

Dry wells are very small infiltration devices similar in design to trenches, except that they are compact in size and not elongated. Due to their small size, the runoff which is directed into these devices should be from a cleaner source such as a rooftop. The small size of dry wells allows their use in very small areas around the site. In order to function properly, as with any infiltration device, they must be sited in areas with permeable soils and must be well maintained.



A dry well is located underground and captures runoff so that it can be released back to the groundwater. The small size of dry wells allows their use in very small areas around the site.

(Illustrations adapted from NCDENR, Water Quality, Stormwater Management Guidance Manual and BMP's)

Although infiltration devices are very efficient at pollutant and sediment removal, the soil pores can quickly become clogged with sediment. When this happens, the ability of the device to capture and infiltrate runoff is diminished and its effectiveness greatly reduced. The use of infiltration devices should be limited to areas which do not generate runoff laden with large amounts of sediment.

The following chart summarizes the charcteristics of several Best Management Practices.

BMP	BEST USES	ADVANTAGES	DISADVANTAGES
Bioretention Areas	Locate in areas upland from inlets or in areas which will be excavated or cut. Used in combination with other BMP's where there are space limitations. Useful in intensively developed urban areas. Can be used on sites where hydrology would not support a wet pond or where soils do not allow infiltration. Designed as an off-line treatment.	Planted bioretention areas can improve landscape value, provide shade and windbreaks. Increases time of concentration of runoff. Provides infiltration and water storage for uptake by vegetation. Provides first flush treatment for concentrated pollutants. Provides several methods of treatment within a single device.	Limited to drainage areas of less than 5 acres. Rigorous maintenance schedule is required. Potential for erosion created by sheet flow. Plants must be carefully selected to be effective. Encroachment of undesirable species must be controlled. Success of the device is dependent upon proper design and installation.
Grassed Swales	Used to convey stormwater in developments by replacing curbs and gutters. Used primarily in single family developments, at outlets of road culverts and in highway medians. Used to connect a series of BMP's. A minimum of 100 feet of swale per acre of drainage area is required although shorter swales can be useful between BMP's. Longitudinal slope of swales should be 2% to 4%. Check dams allow use of swales in steeper areas.	Swales have relatively few failures when properly designed, installed and maintained. Relatively low construction and maintenance cost. Increases the infiltration, and pollutant removal of a stormwater system. Allows elimination of curbs. Swales have a pleasing appearance. Swales cost less than curbs, gutters and underground pipes.	Swales are unable to remove significant amounts of soluble plant nutrients. Excessive velocities may cause thinning of cover, erosion and reduced pollutant removal. Standing water may cause safety, odor or mosquito problems. Special maintenance of mowing and cleanout may become expensive.
Extended Dry Detention Basins	Used to reduce peak discharges, control flooding and prevent downstream channel scouring. Best used in areas which have permeable soils to allow infiltration. Can be used for small and large developments where space allows. Existing dry detention basins can be modified to improve removal of pollutants. Basins should be located out of sight or be concealed with landscape. Not well suited to high density developments.	Well designed basins dry out between rainfall events. Pollutants are removed by allowing particulates to settle out. Basins can be planted in wildflowers to improve appearance and public acceptance. Usually not limited by terrain or soils, however, function best when some infiltration occurs. Provides excellent streambank erosion protection by slowing release rate of runoff.	Usually considered unattractive by the public. Release of water is often too slow to empty basin before next storm event. If storm occurs before basin is empty, pollutants may pass through untreated. Maintenance is essential and costly. Basins are subject to clogging of inlets and outlets. Poor maintenance can result in debris, insects and trash. Pollutants can become re-suspended. Device takes up a large land area. Poorly located basins can remove valuable wildlife habitat and degrade streams and forests.
Vegetated Filter Strips	Best used in combination with other BMP's. Situated between upstream development and receiving waters. Area to be used consists of relatively level land. Designed to spread stormwater runoff into a thin sheet and filter it through a vegetated area. Used primarily in residential areas where development density is low. Used to further treat stormwater from wet detention ponds. Filter strips must be at least 50 feet wide.	Help to reduce peak stormwater flows. Remove moderate amounts of pollutants and sediments from runoff. Visually mesh well with residential areas. Provide for open space and recreation in developed areas. Help to maintain riparian zones along streams. Reduces streambank erosion and provides wildlife habitat.	May be subject to channelization and reduced pollutant removal capability. Improper design or siting may lead to early failure. Must be used in combination with other BMP's. Regular maintenance is required.
Infiltration Devices	Used in areas which have permeable soils, deep water table and deep bedrock. Infiltration basins are used in a location similar to dry detention basins or wet ponds between development and receiving waters. Infiltration trenches are used to handle stormwater runoff from parking lots and buildings. Dry wells are used for receiving runoff from roofs and other impervious areas. Used in areas where stormwater contains little sediment.	Often can fit into areas with limited space. Infiltration devices put more stormwater into the soil and reduce peak flows. Reduces the frequency of downstream flooding. Helps to maintain shallow groundwater and dry weather flows in streams. Very effective removal of pollutants when properly maintained.	Infiltration devices can fail quickly when the soil becomes clogged with sediment. Failure can result in little or no stormwater treatment. Infiltration devices require proper siting, design, installation and maintenance for long term effectiveness. Effectiveness is limited by shallow groundwater, bedrock, or poor soil drainage. Infiltration basins are more expensive than simple dry detention basins.

*(Source of information: Arnold, J.A. et al., 1993, S**tormwater Management Guidance Manual,** and NCDENR-DWQ, November 1995, **Stormwater Best Management Practices**.)*

Wet Detention Ponds	Better suited to large developments. Located downstream of development. Can be used in areas with low infiltration rates. Require larger sites with some open land with suitable topography.	Very effective capacity for removal of pollutants. Ponds are aesthetically pleasing. Provide wildlife habitat. May provide recreation.	High routine maintenance requirements. Strict design requirements. Failure can be catastrophic. Can contribute to thermal polllution. May flood prime waterfowl habitat. Odors, algae blooms or debris can occur if pond is not properly maintained.
Stormwater Wetlands	Extended stormwater wetlands are well suited to sites with a large drainage area. Require use of a larger land area than other BMP's. Not well suited to sites with large amount of impervious area. Pocket wetlands are suited to smaller sites. Are to be used in combination with other BMP's.	May meet or exceed capability for removal of pollutants of a wet pond. Sheet flow across wetlands reduces velocity and allows particles to settle. Efficient in removing sediments and certain pollutants. Increased biological uptake of nutrients associated with wetland plants. Costs for an extended stormwater wetland are similar to a wet pond; costs for pocket wetlands are lower.	May contribute to thermal pollution. Require regular sediment removal and plant harvesting. Subject to short circuiting. Strict design requirements. Extended stormwater wetlands require more land than other BMP's. If a watershed is too small, the wetland may dry out and become a nuisance. Standing water may breed mosquitos. May have difficulty finding a source for wetland plant species. Cleanout access must be provided for all stormwater wetlands. Debris can collect in wetlands, if not maintained.
Sand Filters	Used to treat stormwater from large buildings, access roads and moderate to large parking lots. Useful in urban areas and on sites with restricted space.	Underground filters are practically invisible. Filters strain small particles out of stormwater. Maintenance is relatively simple. Mosquito breeding is usually not a problem.	Above ground sand filters are often unattractive. Sand filters are more expensive to construct than infiltration trenches. No stormwater detention is provided. Sand filters have limited capability for removal of pollutants.

Construction Specifications

The written descriptions of the materials and methods which are to be used in the construction are known as *construction specifications* or *specs*. The specifications are included as part of the CD set to establish standards for quality of both materials and workmanship. A typical set of specs will be divided into sections which relate to various components of the design such as clearing, grading, drainage, paving, landscaping and the rest of the elements from the construction documents.

A section of the specifications should be devoted to the stormwater management components of the site plan in order to ensure that the materials and methods which are used during construction will be of good quality and will be less likely to fail after the project is built. It is extremely important to maintain control over both the materials and the methods which are used in the construction of stormwater management devices.

Items which are specified for use in stormwater components typically include:

- Materials used for sediment/erosion control
- Soils characteristics for constructed devices
- Seeding and planting specifications
- Construction materials
- Geotechnical fabrics
- Pipes, inlets, culverts and other drainage structures
- Concrete, brick and block
- Maintenance measures

The drawings and specifications of the CD set are often necessary to obtain permits and approvals from local, state and federal agencies.

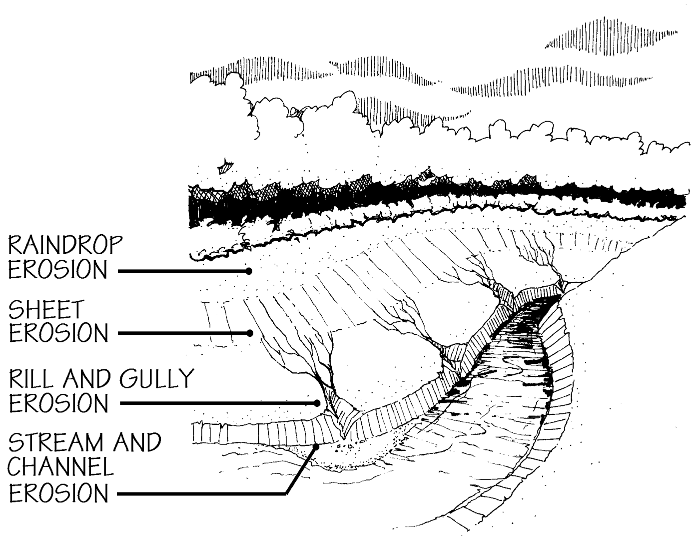
Section Nine

Construction Methods

Once the construction documents for a site plan have been completed and the necessary permits and approvals are in hand, the process of actually constructing the development can begin. Since nearly every type of land use will require at least some disturbance of the site from its natural state, there will be the potential for changes in runoff quantity or quality. When a site is disturbed from its natural state, soil particles and other pollutants are made available to runoff. It is especially important to control runoff on construction sites to prevent these materials from being transported to surface waters.

Sediment and erosion control

The use of approved *sediment and erosion control* methods on construction sites will prevent and control the major sources of sedimentation during the construction phase. At a minimum, the requirements of state or local sediment and erosion control law must be met. The law in North Carolina requires installation and maintenance of sufficient erosion control practices to retain sediment within the boundaries of the site. It also requires that surfaces be non-erosive and stable within 30 working days or 120 calendar days after completion of the land disturbing activity, whichever period is shorter. These time requirements may be shorter when working in certain portions of the state which have special water quality requirements.



It is important to control all types of erosion which can be a source of sediment on a construction site.

(Illustration adapted from ***Michigan Soil Erosion & Sedimentation Control Guidebook)***

Pollutant control

In addition to sediment, a construction site may have other sources of pollution which should be identified and properly managed to protect water quality. Storage areas for machinery and materials which are exposed to rainfall or runoff can be a source of pollutant if the runoff from these areas is not captured and treated before entering surface waters. Equipment wash-down or service areas can also be a problem if they are improperly sited or mismanaged. The best method of controlling the pollution from areas such as this is to prevent the exposure of pollutants to runoff and to control runoff quality as close to the source of pollutant as possible.

Scheduling of construction activities.

A construction schedule should coordinate the timing and sequence of construction activities in order to minimize erosion and sedimentation. Factors which should be considered include weather, growing season, and minimizing the amount of area to be disturbed at one time. The sequence of construction activities on a typical development project include:

- construction access
- sediment traps and barriers
- runoff control
- runoff conveyance system
- land clearing and grading
- surface stabilization
- building construction
- landscape and final stabilization

Tree preservation and protection

The preservation of trees and other existing vegetation on a site requires forethought and planning in order to ensure that they are not damaged or destroyed by construction activities. Direct contact by equipment is the most obvious problem, but damage is also caused by root zone stress from filling, excavating, or compacting soil within the dripline. The storage of equipment, vehicles, and materials under trees can also cause damage and should be discouraged.

Trees to be saved should be clearly marked in the field and the appropriate protection measures installed so that no construction activity takes place within the dripline.

Minimize the extent and duration of exposure.

The amount of time which sediment or other potential pollutant is exposed to rainfall or runoff increases the possibility that it could be carried to surface waters. Exposure can be limited by scheduling construction activities so that large disturbed areas of soil are not exposed at one time, stabilize disturbed areas as quickly as possible, and by using and storing materials in a manner which minimizes exposure to rainfall and runoff.

Protect areas to be disturbed from stormwater runoff.

Runoff should be diverted around or away from areas which are to be disturbed or graded before clearing or grading begin. Dikes, diversions, and waterways are used to intercept runoff and transport it away from cut and fill slopes or other disturbed areas.

Stabilize disturbed areas.

Areas which are cleared, graded, or compacted are much more susceptible to the effects of erosion than undisturbed areas. Once areas have been disturbed, they should be stabilized as quickly as possible. Plans and schedules should show the use of temporary or permanent vegetation, mulches, channel stabilization and other measures which will correspond with construction.

Keep runoff velocities low.

Increases in runoff velocities and volume due to clearing and grading will increase both the erosive energy of the runoff and its ability to carry a greater sediment load. Measures which can be used to reduce runoff velocities during construction include decreasing the length or steepness of slopes, conveying stormwater away from steep slopes and disturbed areas, and mulching or vegetating of exposed areas immediately after construction.

Inspect and maintain control measures.

Once measures have been installed to control runoff on a construction site, they must be regularly inspected and maintained to ensure that they continue to perform well. If not properly maintained, some measures may cause more damage than they prevent. For example, a large sediment basin failure may be hazardous to both people and property as well as the damage it may cause to downstream waters. It is essential to inspect all measures to determine that they are working properly and to correct problems as soon as they develop.

Keep equipment in good working order.

A source of pollutant or sediment on a construction site may result from improperly maintained equipment. For example, construction equipment which leaks fluids or allows part of a load of soil to spill out can deposit materials in areas of the construction site exposing them to runoff. Regular inspections and repair of equipment as soon as a problem is noted is necessary to ensure that leaks and spills do not occur.

Housekeeping/dust control.

Maintaining control over dust, debris, stored materials, and litter on a construction site will reduce the amount of pollutants which are exposed to runoff. Reducing the presence of these materials on a site will result in cleaner stormwater which enters surface waters.

Plan for and minimize stream crossings

Stream crossings can be among the most damaging of construction activties where water quality is concerned. Even a minor stream channel can carry a tremendous amount of flow during storm events. Since stream crossings are the point at which construction activity will come into direct contact with surface waters, there is little margin for error. Even a minor disturbance in the integrity of a natural stream channel can become an erosion problem when subjected to the forces of flowing water.

Wherever streams must be crossed, the crossing should be located at a narrow point in the stream which avoids impact to sidestream wetlands. The crossing should be as near to perpendicular to the stream as possible. All slopes and exposed soil should be stabilized in order to prevent washout. Crossings should be designed to maintain normal flow in the stream as well as to accommodate storm flows.

Sediment and pollution control measures which are in place before and during construction will provide protection to surface waters until the development is completed. In many instances, a well designed system of prevention and control measures can become a permanent part of the site plan. If a site plan closely follows the natural topography and natural drainage patterns are incorporated into the plan, then stormwater management controls used during construction will be more readily converted to permanent measures as construction is completed.

Operation and Maintenance

Once a development has been built and its facilities occupied, a successful operation and maintenance program will ensure that the development remains in good condition for a long period of time. An effective operation and maintenance program can ensure that the ongoing activities are done in a manner which does not generate excessive pollutants or runoff. The program should provide for the maintenance of the site as a whole and should include specific operation and maintenance procedures for the stormwater system components.

Operation and maintenance of the entire site.

The daily activities within a development may be the source of many common pollutants. The proper operation and maintenance of the site as a whole can reduce the amount of pollutants on the site. Maintenance measures which will reduce the amount of pollutant at its source include:

- Street and parking lot cleaning
- Litter and debris control
- Maintain and repair soil surface cover
- Maintain and repair pavements
- Minimize the use of chemicals and fertilizers
- Maintain buffers and setbacks
- Store materials and pollutants away from runoff

Operation and maintenance of stormwater system.

All components of a stormwater management system will require periodic maintenance in order to keep them functioning as designed. The failure to provide proper maintenance reduces the system's pollutant removal efficiency and hydraulic capacity. Lack of maintenance, especially to vegetative systems requiring harvesting or revegetating, can increase the pollutant load of runoff discharges. Even the most well designed system will require periodic maintenance such as:

- Removal of trash and debris from inlet structures
- Dredging of basins which collect sediments
- Clean-out of filters and traps
- Inspection of devices for erosion or wear
- Replacement of worn or damaged structures
- Control of plants or animals which can cause damage to structural integrety of devices.

If development occurs upstream of the site it may become necessary to periodically evaluate and upgrade control measures in order to accommodate increased storm flows.

Integrated Pest Management

The use of Integrated Pest Management methods for the effective control of lawn and garden pests will help to reduce the overall amount of chemical substances available to runoff. An Integrated Pest Management Program (IPM) is one in which horticultural pests are identified as specifically as possible and are targeted with precise applications of chemical or biological pesticides in only the amount necessary to effectively control the pest. An IPM program will emphasize the need to use plants which are indigenous or adapted to an area so that the need for chemical pest control is reduced. Also, the proper environmental siting of plants in the landscape according to their needs, tolerances, or preferences will greatly reduce environmental stress on the plants and they will as a result be less subject to pests or diseases.

The basis of an IPM program is an understanding of the biology of the pest. Every pest will have a period of time during its life cycle in which it is most susceptible to an application of a pesticide. Applying controls at times other than this will often require the use of stronger chemicals, greater amounts, or may not be effective at all.

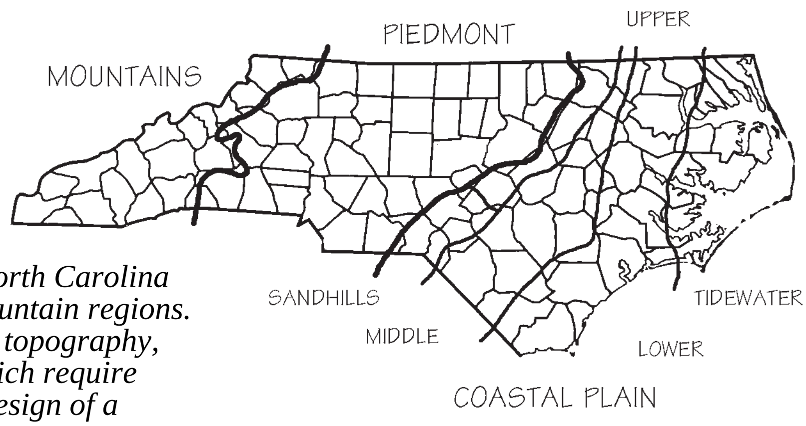
Any reduction in the amount of chemical applied to the landscape will ultimately reduce the amount of that chemical which is available to become a pollutant in stormwater runoff.

The key to effective maintenance is to assign responsibilities to an established agency or organization, such as a local government or homeowners' association, and to regularly inspect the system to determine maintenance needs. An even better tactic is to design a system that is simple, natural, and as maintenance free as possible.

Section Eleven

Special Concerns and Problem Areas

North Carolina has a wide variety of conditions which are encountered across the width of the state. The development situation varies greatly from the mountains to the coast. Each portion of the state has characteristics which present unique opportunities and difficulties when designing a stormwater management system.



Major physiographic regions of North Carolina are the Coastal, Piedmont and Mountain regions. Each region has characteristics of topography, soils, vegetation, and drainage which require special consideration during the design of a stormwater runoff management system.

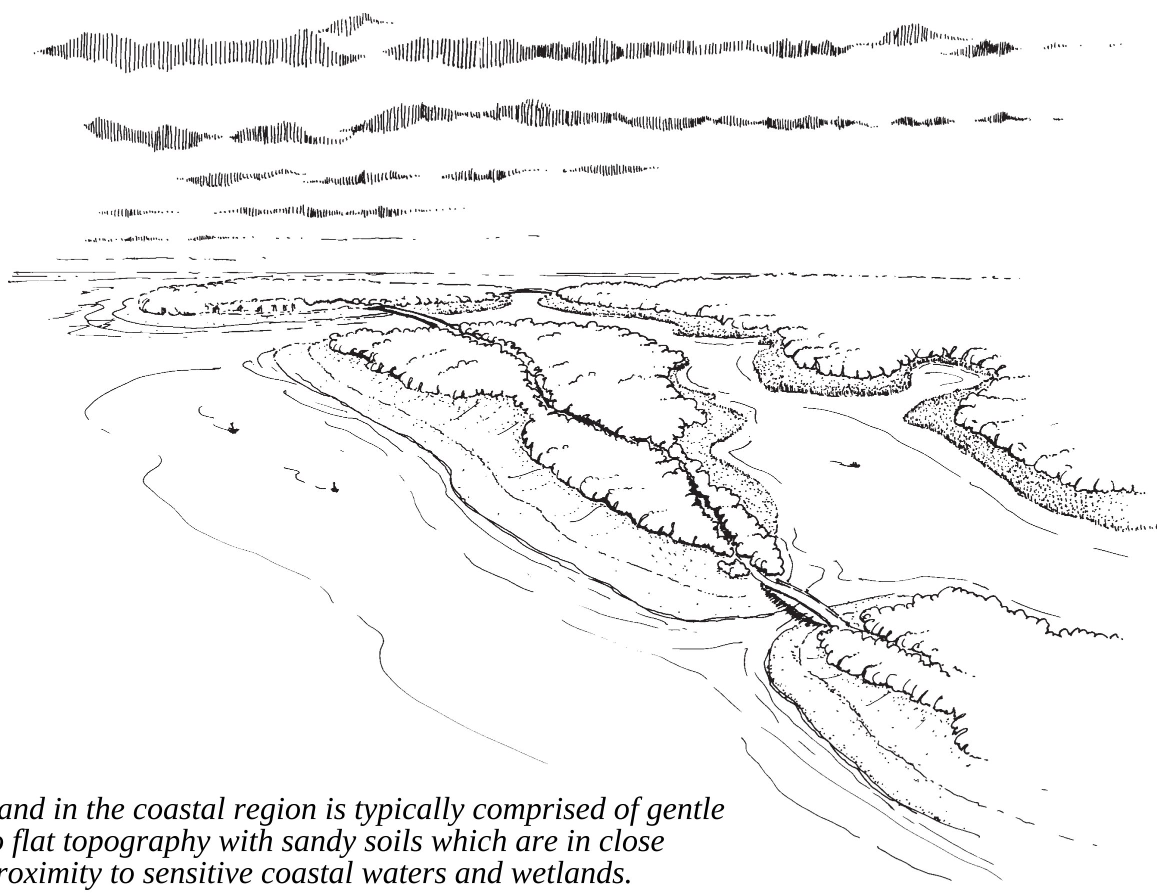
Coastal Considerations

In most parts of coastal areas, the land is relatively flat, the soils are sandy, rainfall can be quite heavy at times, and there is a close proximity to ecologically sensitive resources. While less common, some coastal areas have rolling topography, very shallow groundwater, or dense subsoils with confining layers of clay or hardpan. Conditions such as these present difficulties as well as opportunities to the development of a successful stormwater plan.

The relatively flat topography found in many coastal areas presents a problem to normally engineered drainage solutions which demand a change in grade in order to keep stormwater moving toward pipes, ditches, and other conduits. If an integrated approach is taken to prevent runoff from being generated and infiltrate where possible, this becomes less of a problem. In an integrated approach, the quantity of stormwater being produced is lessened and the distance over which it must flow is decreased. This is accomplished by minimizing impervious area and by incorporating measures thoughout the site to accommodate runoff closer to its source.

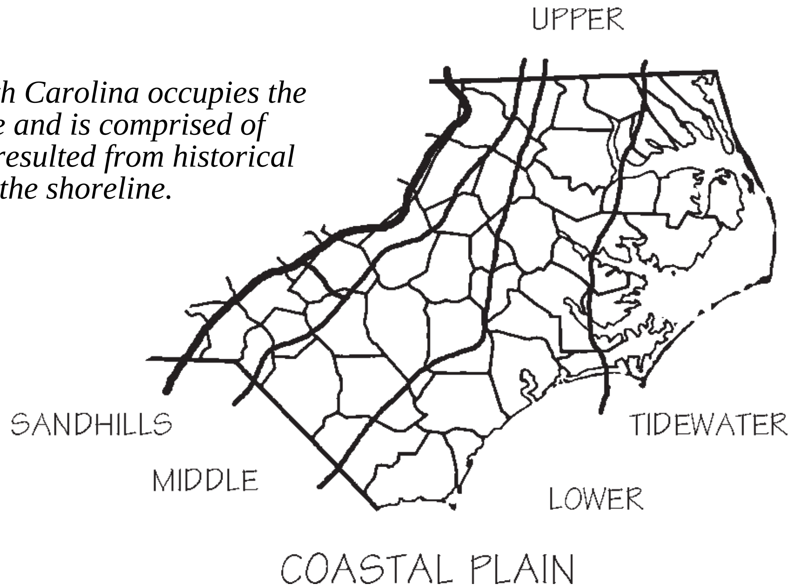
Coastal areas which have steeper slopes present a problem to controlling sediment and erosion. Typically, steeper slopes in coastal areas are the result of relic dune ridges, escarpments, or river deposits. In many instances, the soils are sandy or loamy and due to their depth will provide an opportunity for infiltration if the velocity of runoff can be kept in check. The key to preventing excessive runoff from being generated on a site with this type of character, is to keep the amount of runoff being accumulated at any one time to a minimum by slowing down velocities and directing it toward areas where it can be absorbed. The reliance on many small measures used throughout the site will serve this purpose better than a single large control measure.

Many areas of the coast considered to be the most developable will have relatively sandy soils. Areas which have deeper sandy soils present a greater opportunity to infiltrate runoff close to its source. Although their ability to drain quickly provides the solution to one problem, their lack of filtering capability presents another. Before runoff is allowed to be infiltrated in areas with sandy soils, it should be routed through vegetated areas in order to aid in pollutant removal. These areas include grassed waterways, filter strips, or other such measures.



Land in the coastal region is typically comprised of gentle to flat topography with sandy soils which are in close proximity to sensitive coastal waters and wetlands.

The coastal region of North Carolina occupies the eastern portion of the state and is comprised of several zones which have resulted from historical changes to the location of the shoreline.



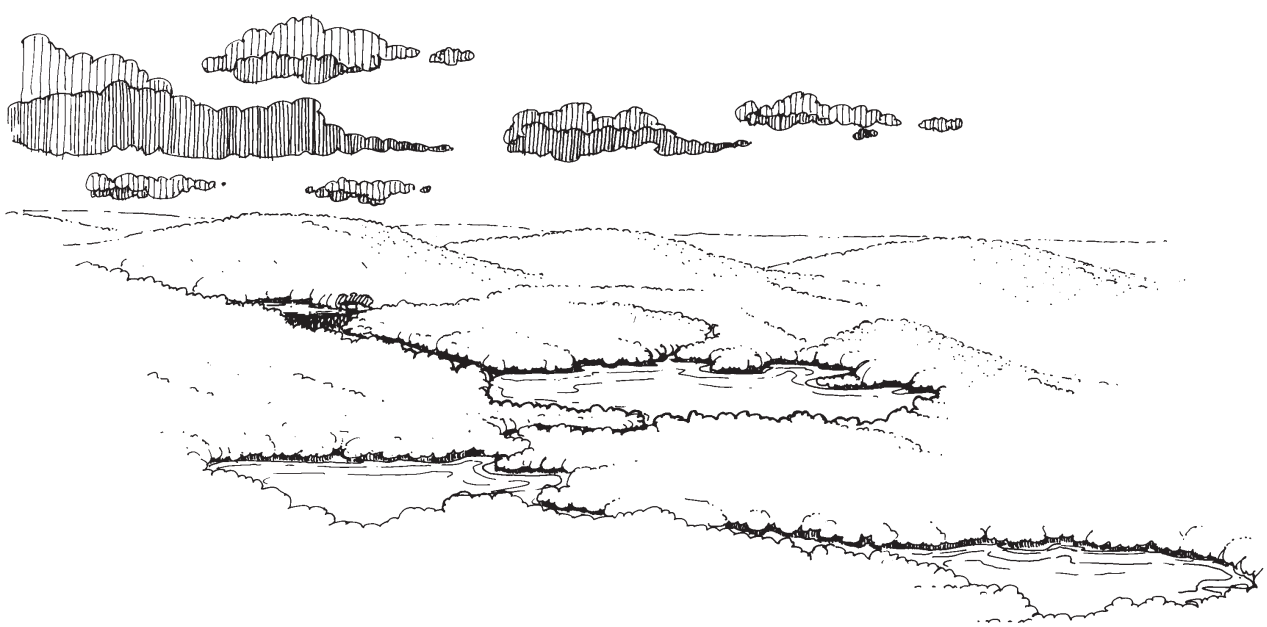
Coastal soils which have confining layers such as hardpans or dense clay subsoil will typically be found in areas which present other problems as well. This type of coastal soil is usually found in areas which have a shallow fluctuating water table, relatively flat topography, or in areas which were previously much wetter and have been drained over the years. The most successful method for use in areas which provide little opportunity for infiltration of runoff is the use of preventive measures to the greatest extent possible . This approach will reduce both quantity of runoff and the amount of pollutant present in that which is generated. The use of additional BMP's, smaller control measures and conveyances integrated throughout the site will enhance the preventive efforts by significantly improving runoff quality.

One of the most important considerations during site planning for a site located within coastal areas is the protection of environmentally sensitive wetlands, estuaries, groundwater, and surface waters. A project located within one of the twenty coastal counties must meet certain minimum stormwater requirements which are designed to help prevent degradation of these resources. These requirements are part of the State Stormwater Management Program. See Appendix 3 for a list of the 20 counties, a map with the counties highlighted, and contact information for the responsible DWQ Regional Offices. A well designed site plan which includes an integrated approach to management of stormwater runoff could be expected to surpass the minimum required levels of resource protection and to provide additional benefit without additional cost or effort than standard approaches, and potentially realize a cost savings.

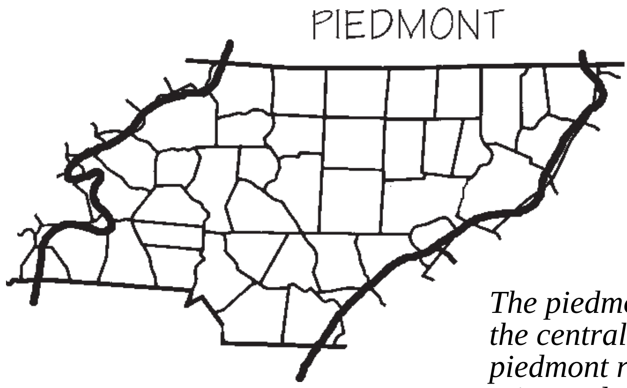
Piedmont Considerations

The piedmont portions of the state represent an average of the conditions found in North Carolina. In most areas of the piedmont, the land is gently to steeply rolling. The topography in most areas is not so steep that it would prevent development from occurring, but steep enough that high runoff velocities can be generated over relatively short distances. Like the mountains and coast, the characteristics of the land in the piedmont presents special concerns and considerations to the planning for stormwater runoff management.

Many of the soils found in the piedmont have a high clay content. The amount of clay in the soil varies greatly depending upon other influencing factors, and will influence the measures taken in the preparation of an effective stormwater management plan. Some of the soils with a lesser amount of clay are loamy and well drained, while others have such a high clay content that they are not well drained and may even have a perched seasonal water table. The degree of internal drainage capability of the soil types found on a site will dictate where the best opportunities for infiltration occur.



Land in the piedmont region is typically comprised of gently rolling topography with clay soils which are in close proximity to streams, lakes and rivers. Many of the largest urbanizing areas of North Carolina are located in the Piedmont region.



The piedmont region of North Carolina occupies the central portion of the state. The geology of the piedmont reflects a transition between the mountains and the coast.

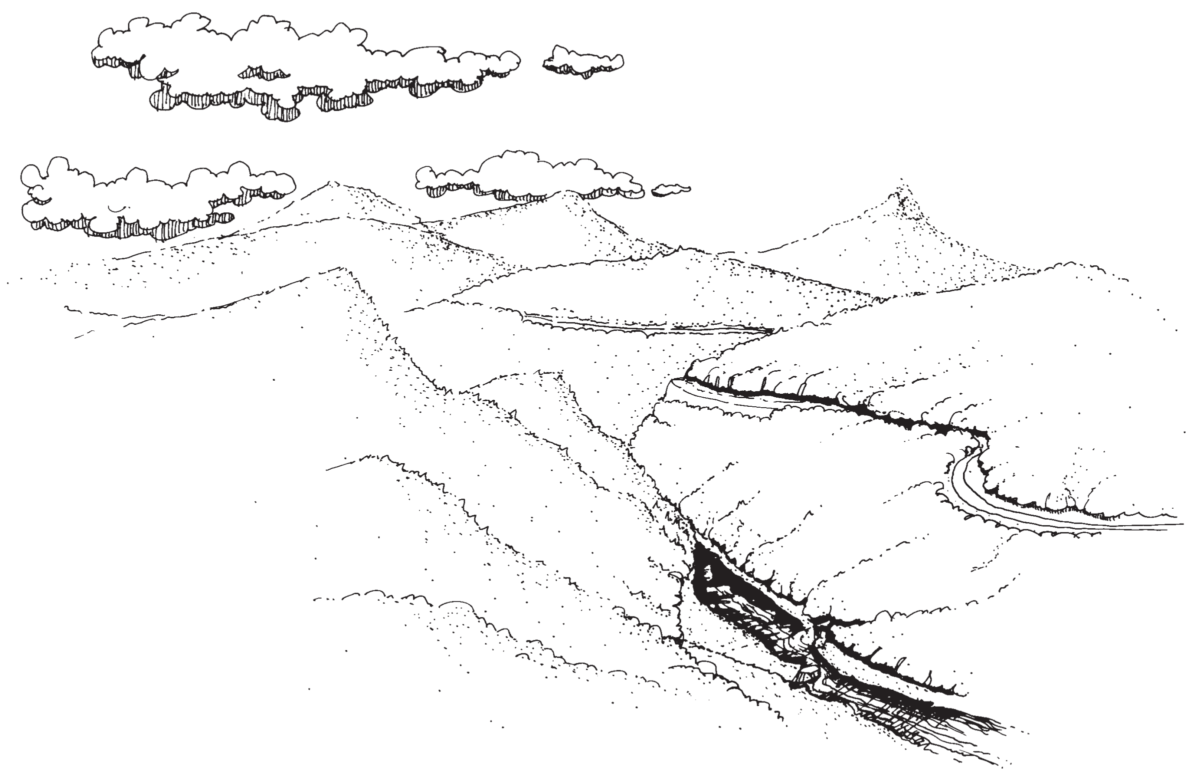
Some of North Carolina's most heavily urbanized areas occur in the piedmont. Due to their urban character and topographic position these areas can generate large amounts of runoff. Urban runoff is typically higher in pollutant content than that from relatively undeveloped land. Every effort which can be made to improve runoff quality in the developing areas of the piedmont will have a positive effect on the quality of water found in downstream rivers.

Since many developing areas of the piedmont are close to urban areas, development sites often fall within watersheds which serve as water supply or recreational waters. Since these areas are sensitive to degradation from pollution, additional stormwater requirements are often necessary in order to control runoff quality. In order to satisfy the more rigorous requirements placed on higher density development, an integrated approach can help to maximize the use of valuable land while maintaining an acceptable quality of stormwater runoff.

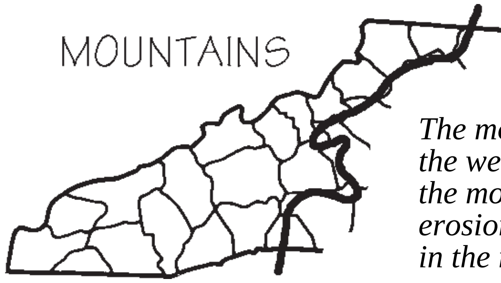
Mountain Considerations

Development sites in the mountainous areas of the state are of two conditions; steep mountain sideslopes or comparatively level river valley bottoms, ridgetops, and floodplains. Each of these conditions presents a challenge to the design of an effective stormwater runoff management plan.

In many portions of the mountains, especially on steeper slopes, not only is the soil subject to tremendous erosion potential, but due to the natural erosion process over the years, the soil that remains is typically underlain by shallow bedrock. The steep slopes combined with shallow soil provide relatively little opportunity for infiltration. This requires that a stormwater management plan emphasize the prevention of runoff through the reduction of use of impervious surfaces where possible and keeping drainage basins as small as possible. Incorporating a variety of surface measures throughout the design will slow runoff velocities and keep peak accumulations from occuring.



Land in the mountain region is typically comprised of gently to steeply rolling topography with clay , loamy, or rocky soils. Much of the most developable land in the mountains is in close proximity to trout streams, and other high quality waters which are very sensitive to degradation. Due to the steeper slopes, very careful attention must be paid to all land disturbances in the mountain region.



The mountain region of North Carolina occupies the western portion of the state. The geology of the mountains is the result of both upheaval and erosion. Many of the major river basins originate in the mountain regions.

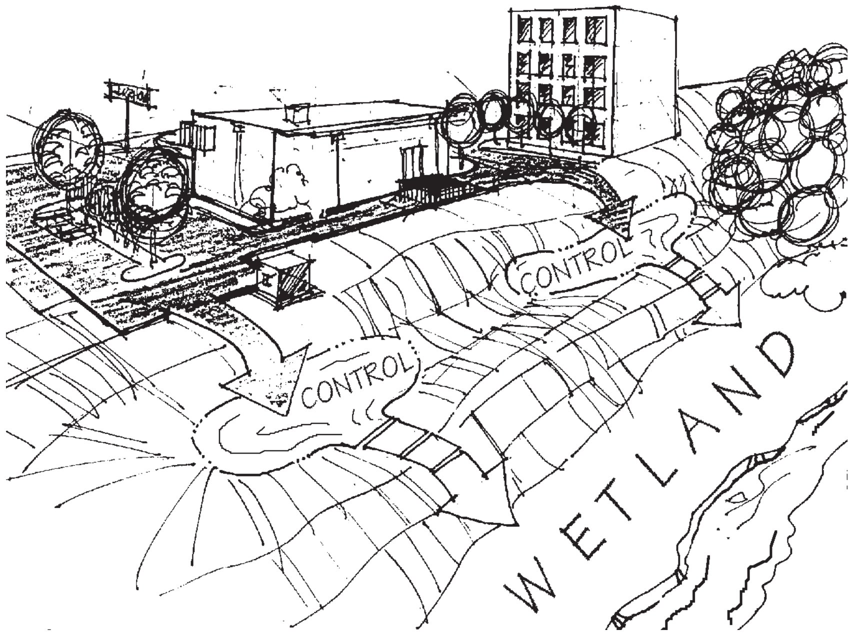
Since the majority of developable land in mountain areas occurs in flatter portions of the landscape topography found along rivers and broad valley bottoms and on some broader ridgetops, these areas are subject to pressure to be developed at a higher than normal density. This development pattern compounds the problem of controlling runoff for two reasons. Typically these areas are subject to peak flows from not only the runoff which is being generated locally, but also to that which is generated at higher elevations. Increased densities of land use results in very little land area left for absorption or infiltration. For these reasons, it is most important to be as effective as possible in controlling the amount of runoff being generated by implementing measures in upper reaches of each basin and throughout the design which will reduce overall runoff quantity and increase runoff quality to the greatest extent possible instead of relying heavily upon downstream control measures.

Two situations which require special care regarding stormwater in the mountain areas are work near trout waters and the potential for flooding of sites located near waterways. Care must be taken when developing near trout waters to control discharges which would negatively affect trout habitat. Trout species are sensitive to thermal pollution as well as chemical or physical pollution. Thermal pollution can result from stormwater contacting heated pavements or other impervious surfaces before it enters the receiving water. Chemicals and sediments found in urban runoff can degrade trout water quality and habitat.

Overbank flooding occurs along many mountain streams and rivers on a regular basis due to the very short time of concentration associated with the steepness of the land. As upstream development continues to increase, the additional flows contributed to watercourses compound the flooding problem along streams in downstream areas. This should be kept in mind when designing a stormwater management system in order to prevent its failure or destruction by future flood events.

Special Problem Areas

Certain types of development or land use present a particular challenge to implementing an integrated stormwater runoff management system. Among the most difficult are the expansive strip retail centers and distribution areas which consist of large unbroken building footprints and vast amounts of surface parking. Since this type of development is mostly impervious area, there is often little opportunity for infiltration. When stormwater management is required for a development of this type, it is usually provided in the form of a single large control measure, typically a wet pond, which is intended to capture and treat the runoff generated by a fairly large contributing basin. Runoff is directed to catch basins and inlets and piped directly into the wet pond. Often the velocities of the runoff entering the wet pond are very high and as a result can carry quite a large pollutant load. If failure or short circuiting occurs in a system such as this the environmental result could be severe, especially if the control structure has not been properly maintained.

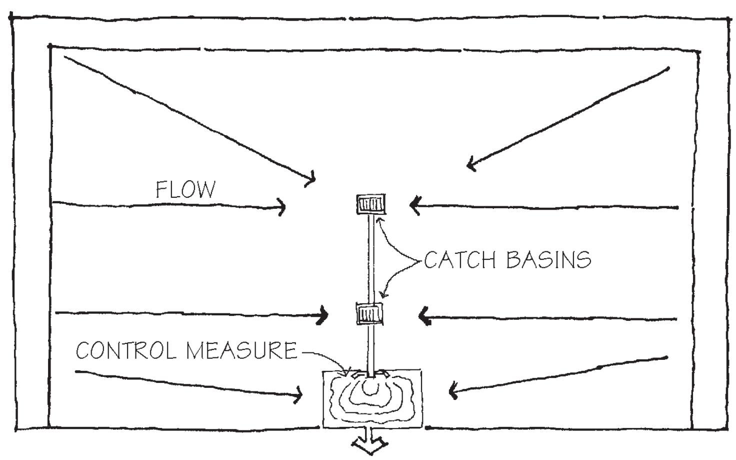


The failure of a single large control measure poses a threat to downstream areas including wetlands and surface waters.

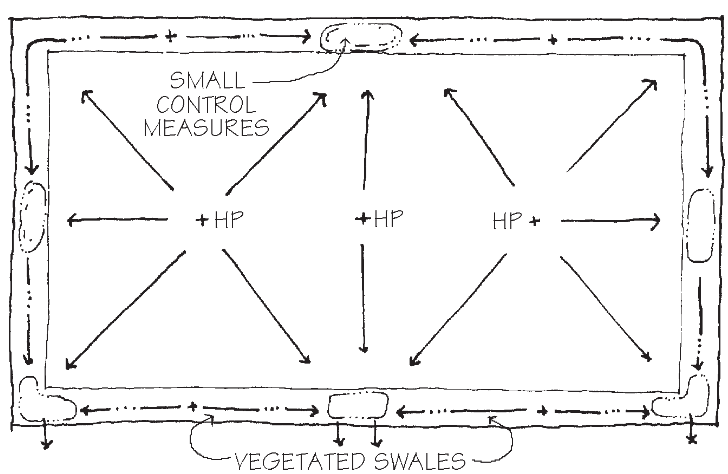
If possible, a more efficient and potentially more cost effective approach would be to design the site in a manner which could reduce the amount of runoff being generated, divide the site into smaller more easily controllable basins, and provide vegetated collection or conveyance devices. Buildings can also be designed in a manner which will temporarily detain runoff generated by rooftops so that it can be released more slowly once the storm has passed. These methods will help to reduce the quantity and velocity of runoff and will help to reduce the pollutant load which would be transported.

The typical commercial development consists of about 90 percent parking area and vehicular circulation. If there is any means of reducing the often under-utilized area dedicated to short term vehicle storage and travelways, the result would be not only aesthetically rewarding, but would significantly reduce the runoff generated by the site. Methods such as shared overflow parking lots, centralized parking emphasizing pedestrian circulation, and multiple use of paved surfaces could be used to acheive this.

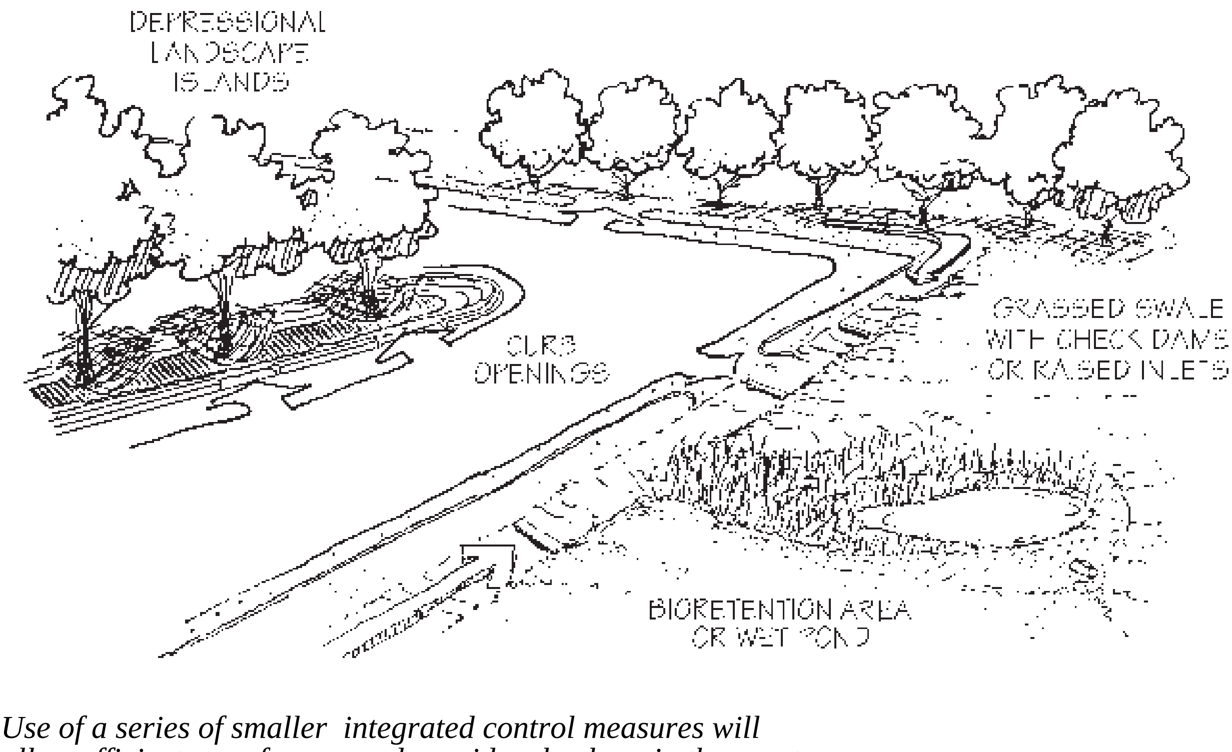
A typical shopping center parking lot collects flow into catch basins and pipes, then routes the flow to a single large control measure.



Where space allows, a more natural method of creating smaller sub-basins and directing flow to grassed swales and smaller control measures may reduce cost and improve pollutant removal from paved areas.

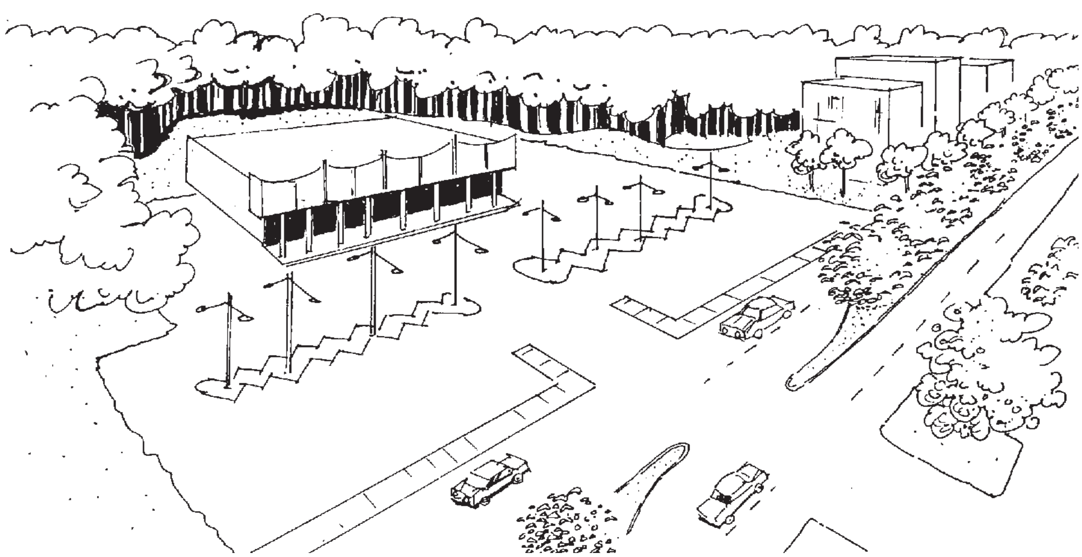


Runoff generated by a shopping center parking lot could be controlled using a series of measures which work together to manage runoff velocity and capture pollutants. Landscaped areas around the perimeter of the parking lot could contain a grassy swale along the curb line to collect and carry surface flow. Curb cuts would allow runoff to flow off the parking lot into the swale. Runoff would then be routed toward a storm sewer inlet which is raised about 6 inches above grade, then to a wet detention basin, bioretention area or other control measure. Curb cuts and raised storm sewer inlets could also be used in depressed landscape islands. An underground cistern could be used, in areas where it would be feasible, for temporary storage of runoff following a series of control measures. Stored water could then be released slowly or re-used for purposes such as irrigation. The underground cistern would be out of sight and would not take up valuable surface land area. Care must be taken when using a measure such as a cistern, that sediments not be allowed to enter the storage device for in a short amount of time, accumulated material could render the storage device useless. It is very important to provide first flush control measures through which runoff is directed before it is routed into the device.



Use of a series of smaller integrated control measures will allow efficient use of space and provide a back-up in the event of failure of an individual component. Smaller measures are especially useful in urbanizing areas where land values are highest.

Other land uses which are a potential sources of stormwater management problems are very dense urban settings which have traditionally collected runoff from buildings and streets into the nearest catch basin and directed the untreated flow into the nearest stream. While it may be extremely difficult or impossible to retrofit existing urban areas to improve runoff characteristics, there may be opportunities to provide measures on new infill developments or re-development which will prevent any new runoff being contributed. Likewise, there may be opportunities downstream of existing urban areas which could be modified to provide some measure of control for the quality of stream flow. Methods which could be incorporated to help improve water quality include dividing stream flows and routing them through vegetated areas, providing pools which will allow sediments to settle, and most importantly, providing maintenance for any new downstream control measures. These methods would be expected to be expensive and difficult to incorporate in many areas, however, any effort which can be realistically employed that will help to improve overall water quality will result in benefits to all who enjoy our water resources.



Pavements contribute to impervious area and pollutant load in urbanizing areas, especially those which are aging or abandoned.

The methods described could be applied in areas which are already partially developed and contribute the runoff they generate into existing municipal stormwater systems as a means of reducing the burden on these systems and contributing to overall improvements in water quality within the watershed. Municipal separate stormwater system (MS4) outfalls to waterways are point source discharges and are permitted through the NPDES program. Even though the discharges from these locations are flowing from a single controlled point, a portion of the discharge was likely collected from a wide area and began as what would otherwise be considered non-point sources before being collected into the system. The use of effective site design and land use planning which considers the quality of surface runoff being generated and collected can reduce the pollutant load being carried and either treated or discharged by these systems.

Preventive measures in densely developed areas which will improve the quality of runoff from pavements and other surfaces include the proper storage of potential pollutant materials, a well managed street and parking lot cleaning program, and careful monitoring of land usage in areas contributing to stormwater collection systems.

Section Twelve

Cost Effectiveness

Stormwater mangement is subject to project economics as much as every other plan component. In order to ensure that a stormwater design is built as intended, it must be designed to be as efficient and cost effective as possible; even on the most expensive of developments. The design of a system which is different than the standard solution of curb inlets, catch basins and pipes presents a challenge. Over time, the use of enclosed piped systems has been an accepted solution to control localized flooding in many urbanizing areas. Since the use of this type of enclosed system is well understood and can be cost effectively engineered, it has been encouraged, and in many areas required.

Like its enclosed counterpart, a well designed, integrated stormwater system which utilizes the natural drainage patterns will provide the basic function of carrying stormwater. In addition to carrying runoff, the more natural integrated system will benefit water quality by providing for a greater degree of infiltration and filtering. When comparing the cost effectiveness of such a system with that of a similar piped system it is important to look at not only the immediate costs, but also the costs associated with long term operation, maintenance, and benefit of each.

Since the success of an integrated system relies on the use of prevention, source reduction practices and control measures to support one another, the amount of runoff and pollutants which are generated on a site using this type of system would be expected to be reduced. Since the quantity of runoff is less, the sizes of structures would not need to be as large or as plentiful.

Appendices

Appendix 1
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Fact Sheet No. 2, **Stormwater Control Practices & Principles.**
Fact Sheet No. 3, **Stormwater Management Roles & Regulations.**
Fact Sheet No. 4, **Local Stormwater Program Elements & Funding Alternatives.**
Fact Sheet No. 5, **Municipal Pollution Prevention Planning.**
Fact Sheet No. 6, **Managing Stormwater in Small Communities: How to Get Started.**
Fact sheet No. 7, **Maintaining Wet Detention Ponds.**
Fact Sheet No. 8, **Plan Early For Stormwater in Your New Development.**
Fact Sheet No. 9, **How Citizens Can Help Control Stormwater Pollution.**

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Appendix 2
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Division of Water Quality
Water Quality Section
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Raleigh, NC 27626-0535
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Fax (919) 733-9919

Regional Offices

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Asheville, NC 28801
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Fax (828) 251-6452

Fayetteville
Wachovia Building
Suite 714
Fayetteville, NC 28301
Phone (910) 486-1541
Fax (910) 486-0707

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919 North Main Street
Mooresville, NC 28115
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Fax (704) 663-6040

Raleigh
3800 Barrett Drive
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Fax (919) 571-4718

Washington
934 Washington Sq. Mall
Washington, NC 27889
Phone (252) 946-6481
Fax (252) 975-3716

Wilmington
129 Cardinal Drive Extension
Wilmington, NC 28405
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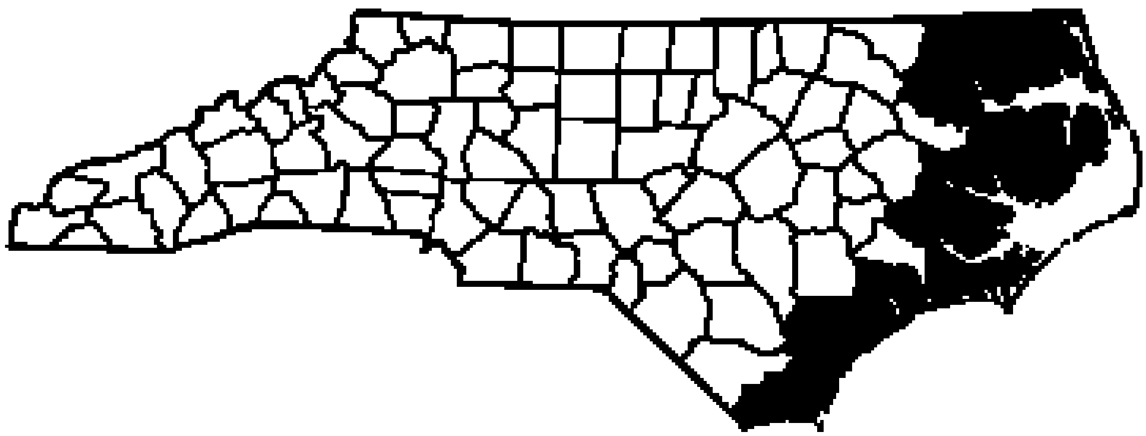
Winston-Salem
585 Waughtown Street
Winston-Salem, NC 27106
Phone (336) 771-4600
Fax (336) 896-7005

Appendix 3
State Stormwater Management Program



<u>The State Stormwater Management Program</u>

The program currently covers the 20 coastal counties of North Carolina. For information contact the appropriate Regional Office

Washington R. O.
934 Washington Sq. Mall
Washington, NC 27889
Phone (252) 946-6481
Fax (252) 975-3716

Beaufort
Bertie
Camden
Chowan
Craven
Currituck
Dare
Gates
Hyde
Hertford
Pamlico
Pasquotank
Perquimans
Tyrrell
Washington

Wilmington R. O.
129 Cardinal Drive Extension
Wilmington, NC 28405
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Fax (910) 350-2004

Brunswick
Carteret
New Hanover
Onslow
Pender