Chapter 9. WATER QUALITY

9.1 Water Quality Regulations

Water quality control is intended to reduce the impacts of development on the quality of the receiving water bodies after construction is complete. Because Greenville County's Phase I MS4 permit requires the County to support a post-construction permitting program, the County's requirements supersede statewide post-construction water quality requirements. The water quality requirement is determined by the location and nature of the development or redevelopment project for which a permit is sought. The County reserves the right to determine that a development must meet separate or additional requirements, so it is advised that a designer discuss water quality requirements early in the design process. Table 9-1 summarizes requirements for each type of development.

Table 9-1: Water Quality Regulations by Location, Downstream Impairments, and Size

Development/ Redevelopment Location	Development/ Redevelopment Characteristics[2]	Water Quality Requirement
Any Development in Greenville County disturbing < 10,000 sf AND Generating no more than 1 cfs increase in peak discharge for the critical storm[3]		None
10,000 square feet – 0.99 acres OR other sites meeting criteria for Alternative TSS Standard (as described in Section 9.1.4)		Ensure annual Total Suspended Solids (TSS) load is ≤ 600 pounds per acre
Not within the Reedy River watershed	1 – 25 acres OR ≥ 25 acres and NOT discharging to impaired waterbody (TMDL or 303d)	Trap 85% of annual TSS load
	≥ 25 acres AND Discharging to impaired waterbody	Trap 85% of annual TSS load AND Anti-degradation Rules for Pollutant of Concern (POC)
Within the Reedy River watershed	1 - 25 acres OR ≥ 25 acres and NOT discharging to impaired waterbody	Trap 85% of annual TSS load AND No Increase in Annual Loading for Total Phosphorus (TP)
	≥ 25 acres AND Discharging to impaired waterbody	Trap 85% of annual TSS load AND Anti-degradation Rules for TP and POC

[2] Size refers to disturbed area. If a development project is part of a larger common plan (LCP) of development, the total area disturbed by the larger common plan should be used for determining water quality requirements.
[3] The Critical Storm is defined in Section 2.2. For most areas of Greenville County, the critical storm is the 25-year, 24-hour storm. Sites less than 10,000 sf disturbed area, but causing more than 1 cfs increase in peak discharge from the site (or any individual outlet) during the critical storm should follow requirements for sites 10,000 sf – 0.99 ac.

The table above is subject to the following exceptions and clarifications:

1. The IDEAL model is the required tool for demonstrating compliance with all standards and is provided by the County at little or no cost to the designer.
2. Compliance with water quality standards must be demonstrated for each outfall individually. An outfall is considered any point where concentrated flow leaves the property or enters waters of the State.
3. The Director has discretion to require more stringent controls for water quality where the Director determines the minimum standards are not adequate. Projects one acre or greater discharging to waters the Director determines are sensitive will be required to follow Anti-degradation Rules. Sensitive waters include outstanding resource waters, trout waters, wetlands, or other sensitive areas.
4. All redevelopment projects and portions of redevelopment projects disturbing more than one acre, or that will result in more than one cubic foot per second (cfs) increase in peak runoff rate during the critical storm (as a site or at any individual outfall) shall meet the requirements of this section even if there is not a change in land use.
5. Exceptions for construction of single-family homes (and/or associated features) will be decided by the Director on a case-by-case basis, depending on potential water quality impacts.

The ensuing sections provide more details and specifics on those types of development or redevelopment projects and their water quality requirements. Sections on pollutant loading, treatment, and best management practices (BMPs) are also included in this chapter.

In addition to meeting one of the above requirements, appropriate structural stormwater controls or non-structural practices must be selected, designed, constructed or preserved, and maintained according to the specific criteria in this manual.

9.1.1 Trap 85% of Annual TSS Load

This standard is applicable to all projects in Greenville County disturbing one acre or greater and not meeting the conditions for application of the Alternative TSS Standard. In some cases, the designer will need to demonstrate compliance with the 85% TSS Trapping standard *in addition to* other requirements for pollutants of concern (e.g., within the Reedy River watershed, designers must demonstrate no increase in annual loading for TP *and* the 85% TSS trapping standard).

The 85% TSS trapping standard requires the designer to show (using the IDEAL model) that 85% of the sediment generated onsite annually, by weight, will be trapped in BMPs onsite. Even manufactured treatment devices (MTDs) or other proprietary devices must be modeled in the software – supplying manufacturer-published literature or tests showing 85% trapping is not acceptable. In an effort to aid the design community as well as to provide the County quantifiable assurances for meeting MS4 permit goals, the County has developed and made available the IDEAL computer program at low or no cost to the designer.

9.1.2 No Increase in Annual Loading

This standard applies to sites subject to antidegradation rules and sites greater than 1 acre in the Reedy River watershed. The IDEAL model is the required tool for demonstrating compliance. To demonstrate compliance, the designer must show that the annual load of the pollutant of concern discharging from the site in the post-construction condition is equal to or less than the load of that pollutant before construction.

9.1.3 Antidegradation Rules for Impaired Waters

The State's Anti-degradation Rules are specifically formulated to ensure that no new activities will further degrade waterbodies that are not presently meeting water quality standards. Greenville County shall ensure compliance with the Antidegradation Rules through though the Stormwater Permitting, Section 401 Water Quality Certificate, Critical Area Planning, and State Navigable Water Permitting program. Greenville County shall implement the Anti-degradation Rules when issuing NPDES permits for point source and nonpoint source loadings into impaired and sensitive waters. The activities of primary concern are land development projects that are immediately adjacent to and discharge stormwater runoff into impaired waters. These projects may also require Special Pollution Abatement as discussed below in Section 9.1.3.3. Antidegradation Rules for Impaired Waters are required for the following projects:

1. Projects 25 acres or greater within a watershed that drains to an impaired waterbody.
2. Projects one acre or greater but less than 25 acres within a watershed that drains to an impaired waterbody if required by the Director.
3. Projects one acre or greater discharging to a waterbody not currently listed as impaired, but that is known to have particular adverse water quality pollutant impacts (including Outstanding Resource Waters), at the discretion of the Director.

9.1.3.1 Definition of Impaired Waterbodies

An "impaired waterbody" is any waterbody that has been listed as impaired by SCDHEC on the most recently published 303(d) list or that has an established TMDL or equivalent. Every two years SCDHEC is required by Section 303(d) of the Clean Water Act to identify waterbodies that are not meeting water quality standards. The impaired waters list includes each waterbody by name, monitoring station number, hydrologic unit, and basin. The impairment and cause should also be identified for each waterbody.

A TMDL document is created by SCDHEC for waterbodies on the 303(d) list for the purposes of reducing the loading of the pollutant of concern. The Total Maximum Daily Load (TMDL) is the total amount of pollutant a waterbody can receive from all sources and still meet the required water quality standard. For some waterbodies SCDHEC and Greenville County will develop a TMDL or equivalent that includes recommended limits or loads for both point sources and nonpoint sources. For some waterbodies, the identified load reduction may apply only to nonpoint sources or point sources.

Waters that are not listed as impaired, but that still require Special Pollution Abatement have been identified by sampling and/or monitoring results and have been identified by the County as priority areas for water quality treatment. Outstanding resource waters may also qualify for compliance with this requirement for protection of their classification.

9.1.3.2 Requirements

Design professionals shall determine whether runoff from the proposed land disturbance contains pollutants that are contributing to impairment of the receiving waterbody. These pollutant discharges will vary from site to site. If stormwater runoff from the proposed land development will contribute pollutants that cause water quality impairment, the design professional must demonstrate that measures and controls implemented will prevent further impairment.

The techniques and controls discussed in Chapter 9 shall be utilized to provide the removal of any harmful pollutants. There is not a specific methodology that must be followed in determining the BMPs selected and utilized to follow the Anti-degradation Rules. However, the calculations and descriptions must show that the water quality BMPs to be installed will ensure that runoff from the site will not cause or contribute to further degradation of the impaired waterbody. This condition will be assumed to be met if the new development or redevelopment does not increase the annual loading of the pollutant of concern over the predevelopment conditions. If the impairment is listed as "BIO" (biological impairment) and/or a metal, TSS shall be considered the qualifying pollutant of concern.

With the IDEAL model, designers can calculate the annual loading for the pollutant of concern for the pre-developed condition as a baseline and the developed condition (with no increase) for impaired waters discharge compliance.

In most cases, the effectiveness of the designed water quality BMPs will not require water quality sampling. However, for certain situations, it may be required for the applicant or landowner to collect monitoring data to confirm the effectiveness of the BMPs.

9.1.4 Alternative TSS Standard

For project sites subject to the conditions listed below, as an alternative to trapping 85% of the annual TSS load, the designer will show, using IDEAL, that the annual post-development load will be no more than 600 pounds/acre/year. The required conditions that must be met to use this alternative are:

1. The designer demonstrates that by the nature of the development, it is impractical to reduce the size of the facility and parking area;
2. The designer shows that there is no space for low impact development (LID) stormwater treatment practices other than proprietary devices;
3. All pervious areas are designed to produce the least amount of runoff practicable.

IDEAL must be utilized to demonstrate the annual loading leaving the site.

9.1.5 Special Pollution Abatement

Special pollution abatement may be required when: 1) development or re-development occurs within a watershed that is listed as impaired by SCDHEC or has an established TMDL, 5R, or equivalent implemented for a pollutant(s) of concern, or 2) an existing development is within a watershed that becomes listed as impaired by SCDHEC or subject to a TMDL, 5R, or equivalent. The purpose of special pollution abatement is to ensure that effective best management practices are used and maintained to control water quality for these waterbodies. The specific applications and requirements will be set by the Director. Any development that occurs without required measures or any existing development that continues to operate after being issued notices of violation shall be in violation of this section of the code.

Development in other areas known to have particular adverse water quality pollutant impacts may also be required to comply with this section at the discretion of the Director. Areas that qualify will have been identified by sampling or monitoring results and will be considered priority areas for water quality treatment. Outstanding resource waters may also qualify for compliance under this section for protection of their classification.

9.1.5.1 Application Procedure

All special pollution abatement requirements shall be included in the final site development plans or as outlined in a remediation plan prepared as a result of a notice of violation. The site plan shall show all development and redevelopment or remediation efforts including discharge points draining to "Waters of the United States" or "Waters of the State", locations of stormwater treatment facilities, and BMPs.

The purpose of a Special Pollution Abatement Permit is to ensure that effective BMPs are used to control water quality for impaired and sensitive waterbodies such that the waterbodies are not degraded any further because of the development or redevelopment. Information for BMPs shall include the following:

- For each proprietary stormwater BMP- manufacturer, model, flow rates of runoff draining to the BMP for the 1-year and 10-year, 24-hour storms, and the verified treatment and bypass flows.
- For each non-proprietary stormwater BMP- type, unique identifying name (e.g., South Dry Pond), and surface area at the highest stage.
- Inspection and maintenance program and schedule for each BMP.
- Certification by the engineer of record that the stormwater treatment BMP will address the pollutant(s) of concern and meets any requirements of the TMDL or equivalent, if applicable.
- Certification by the Responsible Party that the BMP will be maintained and inspected according to the inspection and maintenance program detailed in the permit request. Certified reports shall be submitted to the Director by the Responsible Party of the facility or as the Director requires as given in the permit conditions. Sampling and monitoring may be required to verify the performance of the facility and compliance with the Special Pollution Abatement requirements.

9.1.5.2 Approval of Structural Treatment Devices

If approval of structural stormwater treatment devices is given to address the pollutant of concern, the Director may require valid documentation from full-scale testing by an independent third party to verify that the pollutants of concern will be properly controlled.

9.1.6 New Standard Development Process

The above standards were created for the purpose of protecting the environment and allowing for responsible growth in business and population in Greenville County. Standards exist not to penalize development, but to allow it to fulfill its purpose without reducing or degrading natural resources for future development. Greenville County strives to make the process of receiving a development permit as simple and quick as possible.

Creating water quality standards is an iterative process that began with the state-wide standards as the baseline. During the County's first Phase I MS4 permit cycle, the County instituted a new standard for greater protection of water quality. As a part of that standard, IDEAL was introduced to aid designers in achieving the required level of water quality performance with precision and flexibility. The use of IDEAL eliminates the need for simplistic and outdated methods or excessively conservative design aids and provides the County with measurable and quantifiable proof in meeting our permit requirements.

Due to collaborative efforts with other upstate stakeholders and SCDHEC/USEPA to reduce the discharge of nutrients, the County has developed specific design requirements for the Reedy River watershed. Since Total Phosphorus (TP) is the limiting nutrient for harmful algae blooms in Piedmont-area lakes (Ceballos and Rasmussen, 2007), it was determined that the standards would be based on TP. In general, treating stormwater runoff for the removal of TP will also have a positive impact on total nitrogen (TN). By basing the requirements on TP, the County expects to achieve treatment of both nutrients without adding the extra burden of demonstrating compliance with a TN standard.

9.2 Tools for Compliance with Water Quality Regulations

With any method used for demonstrating compliance, proper documentation of calculations should be supplied, including drawings and details sufficient to confirm the model parameters match the drawings.

9.2.1 Greenville County IDEAL Model

The IDEAL (Integrated Design, Evaluation, and Assessment of Loadings) model for calculating pollutant removal efficiency of BMPs and treatment systems is meant to assist designers and regulators in meeting requirements for any of the potential development or redevelopment scenarios listed in Table 9-1. IDEAL is the County's required method of demonstrating compliance with all water quality requirements.

9.2.1.1 Model Background

The IDEAL model provides Greenville County-specific design methods that give reasonable assurance that stormwater discharges meet desired performance measures without the lengthy design process typically associated with a performance standard. The use of area-specific design methods also provides a means of achieving control without the steep learning curve associated with simulation techniques. The IDEAL model may be used as a tool to show compliance with the 85% TSS Trapping Standard, the Anti-degradation requirements for impaired waters, and the Alternative TSS Standard. It is also suitable for use with nearly any other standard, so changes to standards will not require designers to learn entirely new methods of demonstrating compliance in the future.

The IDEAL Model, a model for post-construction water quality, ties water quality modeling together with physical, chemical, and biological relationships to provide a realistic simulation of processes that are taking place in the real world. Its calculations and results have been validated in actual field installations. The IDEAL model was built around two major processes – pollutant generation from land surfaces and pollutant trapping in BMPs – that are simulated for an annual probability distribution of storms (equivalent to an average year of rainfall in terms of precipitation depths, frequency, and seasonality). Pollutant generation is modeled using Greenville County-specific conditions (soils and climate) adjusted by the designer for the individual site using inputs such as time of concentration, length of flow path, slope of flow path, and land use.

9.2.1.2 Using IDEAL to Demonstrate Compliance with Water Quality Requirements

The IDEAL model assists in streamlining the stormwater permitting application process for new development and redevelopment projects. The IDEAL model is neither rules nor regulations promulgated by the County, but is a tool to design BMPs that meet the applicable water quality requirements. Because the IDEAL model is only a tool for demonstrating compliance, alternative approaches, methodologies and solutions are allowed; however, it is incumbent on one proposing an alternative to adequately demonstrate both the effectiveness and equivalency of that alternative. Likewise, other tools may require additional review time. IDEAL is available through the Greenville County website, but requires a hardware key be mailed, so designers should plan design schedules accordingly.

9.3 Water Quality Background and Loading

The selection and design guidelines set forth in this chapter of the Design Manual for water quality controls are provided to aid the design professional in planning and designing appropriate water quality BMPs relative to target pollutants, function, ease of maintenance, aesthetics, and safety. The design professional is responsible for designing water quality BMPs to function properly for each specific site. It is important to understand the types of pollutants that are present in urban runoff as well as their potential impacts on receiving water bodies. It is equally important to locate the source(s) of these pollutants so source controls can be applied to prevent these pollutants from entering receiving water bodies. Table 9-2 lists typical urban stormwater runoff pollutants and their sources.

Table 9-2: Pollutants and Sources in the Urban Landscape

Pollutant Source	Pollutant of Concern
Erosion	Sediment and attached soil nutrients, organic matter, and other adsorbed pollutants in the ground and in stream banks and beds
Atmospheric Deposition	Nitrogen, hydrocarbons emitted from automobiles, dust, metals, and other chemicals released from industrial and commercial activities

Pollutant Source	Pollutant of Concern
Construction Materials	Metals, paint, VOCs, and wood preservatives
Manufactured Products	Heavy metals, phenols and oils from automobiles, byproducts
Landscape Maintenance	Nutrients, herbicides, and pesticides
Plants and Animals	Plant debris, animal excrement containing nutrients, fecal coliform, and *E. coli* bacteria
Septic Tanks	Fecal coliform and *E. coli* bacteria, nutrients
Non-Stormwater Connections	Sanitary sewage, industrial wastewater, commercial discharge, and construction activities
Accidental Spills	Pollutants of concern depend on the nature of the spill
Animal Waste Management	Fecal coliform and *E. coli* bacteria, nutrients
Pesticide Applications	Pollutants of concern depend on the pesticide being used and the type of crop
Land Disturbance Agriculture	Sediment and attached soil nutrients, organic matter, and other adsorbed pollutants
Fertilizer Applications	Nitrogen and phosphorus

9.3.1 Characterization of Urban Stormwater Runoff Quality

9.3.1.1 Suspended Solids

The most prevalent form of stormwater pollution is the presence of suspended matter that is either eroded by stormwater or washed off paved surfaces by stormwater. Suspended sediment can cause harmful impacts to aquatic life through increased turbidity, which can be harmful to both fish and other forms of aquatic life. The increased turbidity also detracts from the aesthetics of natural waters. In addition, the clogging of fish gills has been attributed to the presence of suspended solids. Contaminants bind to particle surfaces and reside for long periods in the sediment. Sediments are extremely important to ecosystems and serve as a habitat for the benthic community as well as contribute to bioaccumulation and trophic transfer (Burton, 2003). Sedimentation and other forms of physical separation are often an effective means of removing suspended solids from stormwater. Channel stabilization, flow duration, volume management, and/or combinations of these are often necessary in urbanized areas to mitigate bed/bank erosion and should be considered as a part of the strategy for controlling sediment impacts to receiving waters (Leisenring, Clary, Lawler, & Hobson, 2011).

Sediment is derived from a variety of sources, including erosion from disturbed areas, washoff of sediment deposited on impervious areas, and detachment of sediment due to the increased stream power that comes from increased flow rates and flow durations with urbanization. A significant number of models are available to predict total suspended solids (TSS) contributions from "clean" sediment, but few of the models have parameters specific to urbanized areas. Most of the models were developed to deal with agricultural soils, and their application to urban areas is limited. Sediment is a key constituent of water quality due to the physical impact that it can have on aquatic life and aesthetics, but also because sediment in urban runoff is often associated with other pollutants (Leisenring et al., 2011).

9.3.1.2 Nutrients

Nutrient enrichment is one of the top causes of water resource impairment and can cause algae and other aquatic vegetation to develop rapidly, causing both water ecosystem and human health concerns. Nutrients in excess, such as nitrogen and phosphorus, can contribute to the eutrophication of water bodies resulting in associated liabilities such as decreased oxygen supply, alteration of aquatic life, and decreased recreational value (USEPA, July 2000). Excess nutrients can also impair municipal drinking water supplies. Due to excessive phosphorus loading, a reservoir may suffer from algae blooms, low dissolved oxygen, and poor taste (Erikson et al., 2013).

Nutrients are typically derived from agricultural runoff as well as runoff from chemicals applied to lawns in urbanized areas, runoff from industrial sites, municipal wastewaters (of more concern for combined sewer overflows), or dry deposition onto impervious surfaces that is later washed into stormwater. Model studies indicate that the increase in nutrient loading due to increased imperviousness can be dramatic. Nutrients can be removed from stormwater prior to discharge through biological uptake such as by plantings in stormwater quality control ponds.

Most models of nutrient loadings that have an extensive data base included have been based on agricultural and forest operations. These have applicability to washoff from fertilized lawns and forested areas, but not to the impervious areas. Models of nutrient loading in urban runoff are typically based on washoff type calculations or user-defined loadings and concentrations, all of which require user-defined constants and model calibration to monitoring data. Estimating the water quality loading for nutrients is difficult to accomplish without local data.

9.3.1.3 Oxygen Demanding Matter and Bacteria

Sufficient levels of dissolved oxygen (DO) in the water column are necessary to maintain aquatic life, growth, and reproductive activity, as well as to maintain aerobic conditions. The introduction of stormwater containing oxygen-demanding organic matter can impair the receiving water quality by reducing the DO levels such that it is unable to sustain certain forms of aquatic life and can further cause the water to become foul. Bacteria typically enter the stormwater drainage system from the washoff of animal feces and organic matter from the catchment surface. Occasionally, bacteria may enter the drainage system through residential sanitary lateral connections and industrial or commercial drains, although such practices are typically illegal. Further, bacteria can grow within and outside of stormwater systems between storm events, increasing loading even without additional external loading. Pathogenic bacteria and viruses in stormwater discharges pose human health threats. The removal of pathogenic bacteria is achieved primarily through the process of biological decay and physical-chemical disinfection where practiced. Bacteria concentrations may be reduced by designing BMPs that maximize exposure to sunlight, provide habitat enabling predation by other microbes, provide surfaces for sorption, provide filtration, and/or allow sedimentation (Clary, Leisenring, & Jeray, 2010).

9.3.2 Pollutant Loading

Estimating the pollutant load for a particular development site is commonly calculated based on the general land use category of the site. Primary land use contributors are roads, residential areas, commercial areas, industrial areas, and undeveloped areas.

The control of urban runoff can be classified in two categories:

- Runoff quantity control, and
- Runoff quality control.

Quantity control techniques are well established and are based on the physical laws of conservation and momentum. Such measures seek to attenuate peak runoff flow rates and to reduce hydrograph volumes to mitigate flooding and the potential for erosion downstream. Increasing imperviousness leads to hydrographs with shorter durations and greater peak flows, larger flood flows, and smaller base flows (Erikson et al., 2013).

A much more difficult task is the water quality control of urban runoff. This problem is confounded by the intermittent nature of rainfall, the variability of rainfall characteristics, such as volume and intensity, and the variability of constituent concentrations. Tables 9-3 through 9-5 show the various concentrations of constituents in the IDEAL model based on landuse, presented as event mean concentrations (EMCs). For pervious watershed areas, the TSS load is calculated based on the soil, flow length, slope, soil erodibility, a cover & practice factor, and a tendency to rill, instead of a land use-based EMC.

Table 9-3: EMCs for TSS for Impervious Areas

Land Use	EMC- TSS (mg/L)
Low and medium density residential	117
High density residential and office	116

Table 9-4: EMCs for Nitrogen and Phosphorus

Land Use	EMC- Nitrogen (mg/L)	EMC- Phosphorus (mg/L)
Commercial	2.01	0.24
High density residential and office	1.97	0.15
Industrial	1.3	0.09
Low density residential and golf courses	2.06	0.28
Medium density residential	2	0.25
Wooded	0.97	0.2

Table 9-5: EMCs for Bacteria

Land Use	EMC- Bacteria (CFU/100mL)	EMC- E. coli (MPN/100mL)
Residential- public sewer	15,000	11,200
Residential- septic tanks	113,500	78,200
Industrial	7,400	5,700
Open spaces, lawns, parks, etc.	15,000	11,200
Commercial and business	13,600	10,200
Roads and ROW	27,000	19,800
Ag. Cultivation	3,100	2,500
Ag. Livestock	25,800	18,900
Undisturbed woods	1,000	800
Golf courses	3,00	2,400
All land uses	20,000	14,800

9.4 Water Quality Pollutant Removal Mechanics

The removal of pollutants from urban runoff by BMP facilities such as stormwater management ponds and filter strips can occur in a number of ways, which include:

- Sedimentation,
- Decay and biological uptake,
- Filtration,
- Adsorption,
- Nitrification/Denitrification
- Plant uptake, and
- Microbial degradation.

Pollutant removal in stormwater management ponds and detention facilities occurs primarily through the sedimentation of suspended solids. Pollutant removal by decay or biological uptake may also occur under long detention times and favorable environmental conditions.

9.4.1 Sedimentation

9.4.1.1 Quiescent Settling

Quiescent settling is associated with sedimentation in an ideal dry or wet pond. For urban runoff control systems, it is very difficult, if not impossible, to achieve completely quiescent conditions within a storage reservoir, due primarily to the intermittent and random nature of rainfall which results in fluctuations in storage level and variable inflow/outflow rates. For surface detention facilities, wind action and temperature-induced density currents may further affect the quiescent removal of suspended particles. As a result of these limitations, the permanent pools of stormwater management ponds are considered to approximate quiescent conditions only during the inter-event period.

Properly designed storage facilities, such as ponds with long, circuitous flow paths, enhance the sedimentation of suspended solids from the water column; however, it is difficult to ensure a completely mixed and uniformly dispersed concentration of pollutants in the influent runoff. In this regard, deep forebays in stormwater management ponds may be used to reduce the potential for preferential flow paths and dead zones which are induced primarily by the momentum of the influent runoff. In reality, particles that settle out of suspension during one runoff event may be resuspended by a subsequent runoff event, especially for storage facilities which are able to drain completely between runoff events, such as extended detention dry ponds. This resuspension violates the assumption that particles that strike the bottom (or sludge zone) are removed permanently. Again, properly designed facilities with proper inlet protection and proper maintenance should minimize such effects.

9.4.1.2 Dynamic Settling

Storage facilities for urban runoff control, which drain within and between storm events, operate in an unsteady mode with varying inflow and outflow rates, and therefore their removal efficiencies cannot be modeled assuming quiescent settling conditions. Since there is fluid turbulence in such storage facilities, the removal of total suspended solids (TSS) is assumed to occur by dynamic settling.

The pond settling performance factor or turbulence factor, n, is meant to reflect the degree of turbulence and short-circuiting in the flow through the pond (or basin), which is, in turn, affected by the pond geometry (e.g., length-to-width ratio, area-to-depth ratio, inlet and outlet configuration).

Most urban BMPs rely heavily on gravitational settling as a primary pollutant removal pathway. There are limits to the amount of pollutant removal that can be achieved in this pathway. Most removal occurs in the first six to twelve hours.

9.4.2 Decay and Biological Uptake

Some dissolved pollutants and pathogenic bacteria in urban runoff may be removed from the water column by decay or die-off. Other dissolved pollutants may be removed through biological uptake (e.g., nutrients such as organic nitrogen and orthophosphate ion), by means of vegetation in stormwater management ponds and wetlands. The removal efficiencies of these pollutants are often approximated using first-order kinetics.

9.4.3 Filtration

Many particulate pollutants can be physically strained out as they pass through a filter bed of sand, soil, or organic matter, and are trapped on the surface or among the pores of the filter media. The effect of filtration can be very strong. The filtration pathway is not effective in removing soluble pollutants and the smallest particles upon which pollutants are often attached. In addition, the importance of the filtration pathway is a function of the media used in the filter. In relatively tight media, such as soil or sand, filtration is very important, whereas, in more porous media such as compost or peat, the filtration effect is comparatively weak.

Overall, filtration performance depends on many factors including the desired treatment rate, use with other controls, the source water quality, and the physical characteristics of the media. Filtration is an effective treatment option to be implemented in a treatment train. For example, filtration of stormwater before infiltration may minimize groundwater contamination potential. Infiltration has varying risks, depending on the pollutants present, land use, source area, soil characteristics, depth to groundwater, and treatment before infiltration. Filtration is one option for treatment that can be used to reduce risks of infiltration (Woelkers, Pitt, & Shirley, 2006).

9.4.4 Adsorption

The ability of a filtering system to remove soluble nutrients, metals, and organic pollutants is often due to the adsorption pathway, in which ions and other molecules attach to binding sites on filter media particles. In general, the adsorption potential of a filtering system increases when the filtering media has a high content of organic matter or clay, a high cation exchange capacity (CEC), and a neutral to alkaline pH.

Each of the media used for filtering systems exhibit sharply different adsorption potentials. Pure sand, for example, initially has little or no organic matter, clay, or cation exchange capacity, and therefore, little potential for adsorption. Over time, most sand filters develop a thin layer of organic matter and fine particles at the surface as a result of sediment deposition, thereby increasing the adsorption potential. Organic filter media such as soil, peat and compost, on the other hand, have a much greater potential for adsorption, if the pH of the media is in the optimum range.

9.4.5 Nitrification and Denitrification

Nitrification is an important nitrogen removal pathway as organic matter is gradually decomposed. Microbes break down organic nitrogen into ammonia, which is then transformed into soluble nitrate-nitrogen. The nitrification process generally requires an aerobic (oxygen-rich) environment which is characteristic of many filtering systems. As a result, nitrification occurs rapidly in many filtering systems, resulting in the export of low concentrations of ammonia.

Denitrification is the final step in the nitrogen cycle. It is the conversion of soluble nitrate into nitrogen gas that is returned to the atmosphere. To proceed, the denitrification process requires a moist, anaerobic environment, an abundant supply of both organic carbon and nitrate, and the presence of denitrifying bacteria. These conditions are not always met in most filtering systems. Consequently, most filtering systems actually export more soluble nitrate than they receive. In recent years, designers have attempted to create suitable conditions for denitrification within filtering systems, and have demonstrated a capability to remove nitrate.

9.4.6 Plant Uptake

Several filtering systems incorporate plants, such as algae, emergent wetlands or grass to improve removal rates. Examples included vegetated open channels (grass), sand or organic filters (that have a grass cover crop), bioretention (grasses, shrubs, small trees), filter strips (grass), and gravel wetland filters (algae, wetland plants). Plants can increase pollutant removal in several ways. During periods of storm flow, for example, grass and emergent wetland plants provide resistance to flow, thereby reducing runoff velocities. Slower runoff velocities translate into more time for other pollutant pathways to work (such as settling, filtering, infiltration and adsorption). In addition, the roots of grass and emergent plants help bind up the filter media, preventing loss of sediments and attached pollutants via erosion.

The growing plants also create a continual supply of thatch, or detritus, which provide the organic matter needed for greater adsorption. During periods of growth, the plants take up nutrients and metals from the filter bed and incorporate it into their biomass. If plant biomass is harvested or mowed, pollutants are removed. Taken together, however, the use of plants in a filtering system is usually of secondary importance as a pollutant removal pathway in comparison to the other five pathways.

9.5 Water Quality Controls and Techniques

Structural water quality control features are recommended for use with a wide variety of land uses and development types. These controls have demonstrated the ability to effectively treat runoff to reduce the amount of pollutants discharged to the downstream system. Additionally, design techniques exist that can reduce the loading produced by the development, reducing the amount of pollutants that must be trapped on site. Design specifications are provided by Greenville County for the following water quality controls and techniques:

- WQ-01 Dry Detention Basins
- WQ-02 Wet Detention Basins
- WQ-03 Stormwater Wetlands
- WQ-04 Gravel Wetlands
- WQ-05 Bioretention Cells
- WQ-06 Sand Filters
- WQ-07 Infiltration Trenches
- WQ-08 Enhanced Dry Swales
- WQ-09 Infiltration Basins
- WQ-10 Manufactured Treatment Devices (MTDs)
- WQ-11 Permanent Water Quality Stream Buffers
- WQ-12 Vegetated Filter Strips
- WQ-13 Level Spreader
- WQ-14 Rain Garden *(new BMP)*
- WQ-15 Regenerative Stormwater Conveyance *(new BMP)*
- WQ-16 Pervious Pavement *(formerly LID-01)*
- WQ-17 Full Dispersion (*formerly LID-02*)
- WQ-18 Rainwater Harvesting *(formerly LID-03)*

- WQ-19 Vegetated Swale *(formerly LID-04)*
- WQ-20 Stormwater Alley *(formerly LID-05)*
- WQ-21 Split Track and Shared Driveways *(formerly LID-06)*
- WQ-22 Disconnected Impervious Area and Green Spaces *(formerly LID-07)*
- WQ-23 Mountainous & Steep Slope Sites *(formerly M-LID-01)*
- WQ-24 Green Roofs *(formerly U-LID-01)*
- WQ-25 Planter Box *(formerly U-LID-02)*
- WQ-26 Stormwater Courtyards *(formerly U-LID-03)*
- WQ-27 Parking Lot Application *(formerly U-LID-04)*
- WQ-28 Flow Splitter *(formerly U-LID-05)*
- WQ-29 Tree Planting within Swale *(formerly U-LID-06)*

Some of the Specifications above, such as level spreaders (WQ-13), flow dispersion (WQ-17), innovative driveways (WQ-21), and disconnected impervious areas (WQ-22), do not explicitly reduce pollutant loads by treating runoff from other areas. Level spreaders distribute concentrated flow over the width of a BMP without providing any further water quality treatment; instead, this practice facilitates the use of vegetated filter strips and potentially other BMPs. Flow dispersion is a technique whereby runoff from a relatively small amount of impervious area may be disbursed over a larger amount of pervious, undisturbed area. Innovative driveways are simply methods of reducing the impervious cover by using wheel tracks - these practices are incorporated into the site's curve number and impervious area calculations. Disconnected impervious area describes the practice of directing rooftop and parking lot runoff to pervious areas instead of directly into a piped stormwater system. Permanent stream buffers (WQ-11) are not required, but may be used in conjunction with the requirements of the Tree Ordinance to treat stormwater runoff.

Greenville County technical specifications and details for these Post Construction Water Quality BMPs are located Appendix G. Table 9-6 gives descriptions for each BMP.

Table 9-6: BMP Descriptions

BMP Specification Name	Description
WQ-01 Dry Detention Basin	A dry detention pond does not maintain a permanent pool and is intended to manage both the quantity and quality of stormwater runoff before discharging off-site.
WQ-02 Wet Detention Basin	A wet stormwater pond has a permanent pool or micropool of water. Runoff from each rain event is detained and treated in the pool, and released at a designed rate.
WQ-03 Stormwater Wetland	A stormwater wetland is designed to mimic a natural wetland with a shallow permanent pool and wetland plantings. Runoff is treated in the pool before release.
WQ-04 Gravel Wetland	Gravel wetlands are similar to stormwater wetlands with filter media incorporated. These BMPs treat stormwater through detention and filtering.
WQ-05 Bioretention	A bioretention cell is a shallow stormwater basin or landscaped area that utilizes engineered soils and vegetation to capture and treat stormwater runoff. Runoff may be returned to the conveyance system or partially exfiltrated into the soil.

BMP Specification Name	Description
WQ-06 Sand Filter	A sand filter is a multi-chamber structure designed to treat stormwater runoff through filtration, using a sand bed as its primary filter media. Filtered runoff may be returned to the conveyance system or partially exfiltrated into the soil.
WQ-07 Infiltration Trench	An infiltration trench is an excavated trench filled with stone aggregate used to capture and allow infiltration of stormwater runoff into the surrounding soils from the bottom and sides of the trench.
WQ-08 Enhanced Dry Swale	An enhanced bio-swale is a vegetated open channel that is explicitly designed and constructed to capture and treat stormwater runoff within dry or wet cells formed by check dams or other structures.
WQ-09 Infiltration Basin	An infiltration basin is a shallow, impounded area designed to temporarily store and infiltrate stormwater runoff. The size and shape can vary and designs can use one large basin or multiple smaller basins throughout a site.
WQ-10 Manufactured Treatment Device (MTD)	An MTD uses the movement of stormwater runoff through a specially designed structure to remove target pollutants. They are typically used on smaller commercial sites and urban hotspots. There are numerous commercial vendors of these structures, but there is limited data on the performance of these structures. These structures may require monitoring to verify specific pollutant removal efficiencies.
WQ-11 Permanent Water Quality Stream Buffer	Stream buffers are required by the Tree Ordinance, but if the requirements of this BMP Specification are used, a portion of the buffer area may be used for water quality treatment. A level spreader and grassed VFS must be outside of the required buffer.
WQ-12 Vegetated Filter Strip	A VFS is grassed area preceded by a level spreader. Incoming flow is spread throughout the width of the grassed area and allowed to sheet flow over the grassed area, infiltrating and filtering through the vegetation.
WQ-13 Level Spreader	Level spreaders do not provide any water quality treatment, but spread concentrated flow out to utilize VFSs and stream buffers.
WQ-14 Rain Garden	Rain gardens are small versions of bioretention cells without outlet structures. They treat small amounts of runoff through detention and filtration.
WQ-15 Regenerative Stormwater Conveyance	Regenerative stormwater conveyances, also known as step pool storm conveyances, blend characteristics of stream restoration and bioretention. This BMPs is a series of pool and riffles that slow runoff velocity and promote filtering and infiltration.

BMP Specification Name	Description
WQ-16 Pervious Pavement	Pervious pavement captures stormwater through voids in the pavement surface and attenuates water in an underlying aggregate reservoir. The reservoir typically allows some water to infiltrate into the soil subgrade. This BMP includes permeable pavers, pervious concrete, pervious asphalt, porous pavement, reinforced grid systems, and other names.
WQ-17 Full Dispersion	Full dispersion describes the conditions under which runoff from an impervious area may be considered to be treated sufficiently by surrounding undisturbed area.
WQ-18 Rainwater Harvesting	Rain Barrels, Cisterns, and Dry Wells are rainwater harvesting BMPs that are generally used to retain a predetermined volume of rooftop runoff. Dry wells may also function as modified catch basins to catch direct surface runoff.
WQ-19 Vegetated Swale	Vegetative Swales are designed and installed as an alternative to hard piping stormwater conveyance systems. Vegetative Swales improve water quality by providing partial pollutant removal as runoff is filtered by the vegetation and by the opportunity to infiltrate into the underlying soil layer.
WQ-20 Stormwater Alley	A Stormwater Alley or service alley is designed as a private, one-way street with connections to larger public streets on both ends of an urban residential development. Stormwater alleys are only applicable for highly developed urban areas that have blocked street layouts
WQ-21 Split Track and Shared Driveways	Innovative design of driveways can reduce the amount of runoff and pollution produced.
WQ-22 Disconnected Impervious Area and Green Space	Disconnecting impervious areas slows the velocity of runoff and increases overall time of concentration. Green spaces reduce the amount of runoff and pollution produced.
WQ-23 Mountainous & Steep Slope Sites	This BMP is a collection of practices, including the use of seepage cisterns, for development on sites with steep slopes.
WQ-24 Green Roof	A Green Roof or Rooftop Garden is a vegetative layer grown on a building rooftop. Both intensive and extensive varieties may be used.
WQ-25 Planter Box	Planter boxes are similar to bioretention cells in functionality, but may be placed in tight urban settings next to buildings or adjacent to roadways.
WQ-26 Stormwater Courtyard	Stormwater Courtyards are vegetated stormwater treatment areas that detain stormwater runoff and allow the runoff to filter through a soil media bed. Stormwater Courtyards have a shallow depression that contains aesthetically pleasing, water tolerant plantings and can be designed to include an underdrain system.
WQ-27 Parking Lot Application	The parking lot application is a detail showing a method of capturing the parking lot runoff and diverting to a BMP.

BMP Specification Name	Description
WQ-28 Flow Splitter	A flow splitter box may be used to divert runoff with erosive velocities around a BMP to prevent destruction of the BMP.
WQ-29 Tree Planting within Swale	Planting trees in swales must be done according to this detail.

9.5.1 Infiltration BMP Requirements and Soil Testing

9.5.1.1 Infiltration BMP Design

Infiltration BMPs shall be designed for the prevention of clogging by fine materials and for ease of cleaning with conventional cleaning equipment. This may include, but not necessarily be limited to, wrapping the underdrain or other underground structure (perforated pipes/chambers/trenches) with an appropriate fabric and providing sufficient clean outs for the system.

Infiltration systems shall have an overflow to a positive drainage system with a control device, if necessary, between the subsurface system and the positive drainage system. The overflow pipe shall be sized for the allowable discharge.

9.5.1.2 Soil Testing for Infiltration BMPs

Soil testing for infiltration rates shall be performed by a licensed geotechnical engineer. The initial test elevation location shall be at the same contour elevation as the bottom/invert of the infiltration BMP.

Infiltration BMPs shall be designed on the basis of actual test data. Tests shall be consistent as to soil conditions, proposed BMP elevations, locations, and water table depths for the proposed infiltration BMP system. The following tests are typically allowable to determine infiltration rate for soils, though some BMP specifications only allow a subset of these (other test methods must be approved by the County):

- Laboratory Permeameter Test for saturated hydraulic conductivity on undisturbed soil samples (ASTM D 5084).
- Double Ring Infiltrometer Test to estimate the initial vertical unsaturated permeability data of the upper soil layer (ASTM D 3385).
- Constant Head Test in soils with permeability that allow keeping the test hole filled with water during the field test (AASHTO T 215).
- Falling Head Test in areas with excellent soil percolation where keeping the test hole filled with water is not feasible during the test.

The Engineer is responsible for obtaining documentation of test results and providing them to the County.

9.5.1.3 Filter Media Testing for Infiltration BMPs

When Infiltration BMPs utilize a filter media, the filter media will be tested for appropriate infiltration rate before it is installed. Once installed, the BMP will be tested again to ensure installed infiltration rate is acceptable. Soil testing for infiltration rates shall be performed by a licensed geotechnical engineer.

The installed filter media test elevation location shall be at the surface of the BMP. Acceptable test methods for filter media are the same as those for soil as listed in Section 9.5.1.2. The Engineer is responsible for obtaining documentation of test results and providing them to the County.

9.5.2 Relative Pollutant Removal Capability

Several generalizations can be made about the overall performance of stormwater treatment systems. In general, they exhibit a high capability to remove suspended sediments and a moderate ability to remove total phosphorus, nitrogen (although low or negative with respect to soluble nutrient forms), and bacteria.

Table 9-7 provides a general comparison of expected pollutant removal rates relative to each other. Actual removal rates for a particular design may differ from than those shown in Table 9-7, and depend greatly on loading rate, BMP specifications, and BMP size. For example, a dry pond can achieve extremely high removal rates for all pollutants if the underlying soil infiltrates quickly and has a large surface area. As another example, there are manufactured treatment devices specifically designed to capture certain pollutants like bacteria, even though most are not.

Table 9-7: Relative Pollutant Removal Capability for BMPs

BMP	Relative Pollutant Removal Capability		
	TSS	Nutrients	Bacteria
WQ-01 Dry Detention Basin	Medium	Low	Low
WQ-02 Wet Detention Basin	High	High	Medium
WQ-03 Stormwater Wetland	Medium	Medium	Medium
WQ-04 Gravel Wetland	Medium	Medium	Medium
WQ-05 Bioretention	High	High	High
WQ-06 Sand Filter	High	Medium	Medium
WQ-07 Infiltration Trench	High	High	High
WQ-08 Enhanced Dry Swale	Low	Low	Low
WQ-09 Infiltration Basin	High	High	High
WQ- 10 Manufactured Treatment Device (MTD)	Medium	Low	Low
WQ-11 Permanent Water Quality Stream Buffer	Medium	Medium	Low
WQ-12 Vegetated Filter Strip	Medium	Medium	Low
WQ-13 Level Spreader	N/A	N/A	N/A
WQ-14 Rain Garden	High	High	High
WQ-15 Regenerative Stormwater Conveyance	High	High	High
WQ-16 Pervious Pavement	Low	Low	Low
WQ-17 Full Dispersion	Low	Low	Low
WQ-18 Rainwater Harvesting	High	Medium	Medium
WQ-19 Vegetated Swale	Low	Low	Low
WQ-20 Stormwater Alley	High	High	High
WQ-21 Split Track and Shared Driveways	N/A	N/A	N/A
WQ-22 Disconnected Impervious Area and Green Space	N/A	N/A	N/A
WQ-23 Mountainous & Steep Slope Sites	Low	Low	Low
WQ-24 Green Roof	Medium	Medium	Medium

BMP	Relative Pollutant Removal Capability		
	TSS	Nutrients	Bacteria
WQ-25 Planter Box	High	High	High
WQ-26 Stormwater Courtyard	High	High	High
WQ-27 Parking Lot Application	N/A	N/A	N/A
WQ-28 Flow Splitter	N/A	N/A	N/A
WQ-29 Tree Planting within Swale	N/A	N/A	N/A

9.6 Additional Water Quality Controls

These additional water quality controls are not constructed BMPs, but are practices that can reduce the loading of pollutants reaching receiving waters. These should be implemented whenever possible, and can even help meet water quality requirements when utilized properly.

9.6.1 Disconnected Rooftop Drainage to Pervious Area

Disconnected rooftop drainage can reduce the runoff flow rates from developed areas. The disconnection involves directing stormwater runoff from rooftops towards pervious areas where it is allowed to filter through vegetation and other landscaped material and infiltrate into the soil. This practice is applicable and most beneficial in low-density residential or commercial developments having less than 50 percent impervious area. Disconnection is not applicable to large buildings where the volume of runoff from the rooftops will cause erosion or degradation to receiving vegetated areas.

The disconnection of rooftop drainage has the following benefits:

- Increases the time of concentration by disconnecting runoff from any structural stormwater drainage systems.
- Provides water quality benefits by allowing runoff to infiltrate into the soil. Downspouts from rooftops should discharge to gently sloping, well-vegetated areas, vegetated filter strips, or bio-retention areas. Erosion control devices such as splash blocks or level spreaders may be required at the downspout discharge point to transition the flow from concentrated flow to sheet flow.

9.6.2 Cluster Development to Conserve Natural Areas

Cluster development practices concentrate development away from environmentally sensitive areas such as streams, wetlands, and mature wooded areas. The clustering of development in one area reduces the amount of roadways, sidewalks, and drives required when compared to development sprawled over the entire land area.

Clustering and conservation of natural area practices shall be installed at least to some extent on all development sites, not only to reduce the impacts to natural resources by minimizing disturbance and impervious areas, but also to maintain some of the natural beauty of the site.

Reducing the amount of disturbed area and impervious area reduces the amount of runoff volume treated for water quantity and water quality control. Concentrating development away from environmentally sensitive areas will also reduce the amount of time and expenses to get federal and state permits for impacting jurisdictional waters.

Development should be concentrated on the flattest part of the development parcel away from environmentally sensitive areas such as steep slopes, streams, and wetlands. This will not only reduce the impacts to these areas, but may reduce the amount of earth moving necessary for the development.

9.6.3 Innovative Technologies

Innovative technologies are encouraged and shall be accepted providing there is sufficient documentation as to the effectiveness and reliability of the proposed structure. To justify the efficiency of innovative water quality control structures, the owner may be required to monitor the pollutant removal efficiency of the structure. If satisfactory results are obtained, the innovative water quality structure may be used and no other monitoring studies shall be required. If the control is not sufficient, other onsite and/or downstream controls shall be designed to trap the required pollutants.

9.7 References

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