Town of Huntersville
Water Quality Design Manual

November 2017 Edition

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Prepared for:
Town of Huntersville

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For more information, contact County Storm Water Services' Water Quality Program Manager at 980-314-3217. Additional information is also available on the following website: http://stormwater.charmeck.org

Section 1. Purpose of Manual

The purpose of this document is to provide the information necessary for compliance with the Huntersville Post-Construction Ordinance (a.k.a. Huntersville Water Quality Ordinance) adopted by the Huntersville Town Board on February 17, 2003 and incorporated into the Huntersville Zoning Ordinance. Appendix A contains a copy of this Ordinance. The goal of the Ordinance and this manual is to establish storm water management requirements and controls to prevent surface water quality degradation to the extent practicable in the streams and lakes within the Town Limits and Extraterritorial Jurisdiction of Huntersville and to protect and safeguard the general health, safety, and welfare of its residents. Low Impact Development (LID) best management practices (BMPs) combined with conventional BMPs are the primary mechanisms discussed in this document for meeting this goal and complying with the Ordinance.

LID is a technology-based system for managing urban storm water runoff that combines a hydrologically functional site design with pollution prevention measures to compensate for land development impacts on hydrology and water quality. To be effective, LID should be applied to every phase of site planning, design, development and post-construction control for the purpose of mimicking predevelopment site hydrology by storing, infiltrating, evaporating and detaining storm water runoff. Examples of the LID techniques include reducing impervious surfaces, managing storm water closer to the source and avoiding large centralized management devices, phased grading, and vegetated conveyances instead of storm drain piping. The principal goal of LID is to ensure maximum protection of the ecological integrity of the receiving waters by maintaining the watershed’s hydrologic regime. In contrast, conventional storm water management techniques seek to alter the watershed’s hydrologic regime by conveying runoff into piping systems and centralized storm water management devices to quickly and efficiently remove storm water from the development site. Most development practices follow this conventional approach to storm water management.

The Huntersville Post-Construction Ordinance does not require strict adherence to the LID techniques described above. Instead the Ordinance combines LID and conventional storm water management techniques to form a hybrid LID approach. This is necessary because most of the developments in the Town of Huntersville are required to adhere to standard urban design techniques, which make it extremely challenging and expensive to implement the purist LID approach. One of the post-construction components of LID is the LID BMP, which is a single structural device that utilizes the LID principles of infiltration, evaporation, retention and detention as well as biological and physical processes to treat storm water runoff. The use of LID BMPs is required by this Ordinance unless mitigation practices are approved and implemented. Although not required, developers are encourage the use as many of the other LID techniques as possible in combination with LID BMPs, which is the most effective and efficient combination for managing storm water runoff and facilitating compliance with the Purpose of this Ordinance as described in Section 8.17.1. Sections 4 and 5 of this document provide details for implement of the full range of LID techniques. Sections 6, 7 and 8 focus on the LID BMP requirements the Ordinance. LID techniques and BMPs will be included in the Concept Plan Application submitted during the Preliminary Plan review process. Detailed designs will be provided with the submittal of the Storm Water Management Permit Application following approval of the Concept Plan.

The following website provides additional guidance and information for compliance with the Huntersville Post-Construction Ordinance: http://stormwater.charmeck.org (select "Regulations," Select "Huntersville," select "Post-Construction (PCSO)"). A copy of the Administrative Manual developed for the Ordinance is available on this website along with all necessary forms, a process guide, and a variety of other important information.

Section 2. Definitions

The following terms are defined for use with this Manual.

Administrative Manual: A manual developed by the Storm Water Administrator and distributed to the public to provide information for the effective administration of the Huntersville Post-Construction Ordinance, including but not limited to application requirements, submission schedule, fee schedule, operation and maintenance agreements, criteria for recordation of documents, inspection report forms, requirements for submittal of bonds, and a copy of the Ordinance.

Best Management Practices (BMPs): A structural or non-structural management-based practice used singularly or in combination to reduce non-point source input to receiving waters in order to achieve water quality protection goals.

- Non-structural BMPs - Non-engineering methods to control the amount of non-point source pollution. These may include land-use controls and vegetated buffers.
- Structural BMPs - Engineered structures that are designed to reduce the delivery of pollutants from their source or to divert contaminants away from the waterbody.

Bioretention: The use of vegetation in retention areas designed to allow infiltration of runoff into the ground and transpiration by plants as well as evaporation. The plants provide additional pollutant removal and filtering functions while infiltration allows the temperature of the runoff to be cooled. Also referred to as a Biofilter or Rain Garden.

Built-Upon Area (BUA): That portion of a development project that is covered by impervious or partially impervious surface including, but not limited to, buildings; pavement and gravel areas such as roads, parking lots, and paths; and recreation facilities such as tennis courts. “Built-upon area” does not include a wooden slatted deck or the water area of a swimming pool. The methodology used for calculating Built-Upon Area percentage can be found in the Charlotte-Mecklenburg BMP Design Manual.

Charlotte-Mecklenburg BMP Design Manual: A document that contains designs for BMPs. The Huntersville Water Quality Design Manual and/or the Huntersville Post-Construction Ordinance indicate the designs from the Charlotte-Mecklenburg BMP Design Manual that are approved for use in the Town of Huntersville for compliance with the Ordinance. The Charlotte-Mecklenburg BMP Design Manual shall be approved for use in the Town of Huntersville by the North Carolina Department of Environment and Natural Resources and shall be at least as stringent as the storm water design manual approved for use in Phase II jurisdictions by the Department for the proper implementation of the requirements of the federal Phase II storm water program. All references herein to the Charlotte-Mecklenburg BMP Design Manual are to the latest published edition or revision.

Cistern: A receptacle for holding water or other liquid (i.e. tank for catching and storing rainwater).

Conventional BMPs: Storm water treatment devices that are not LID BMPs as defined below.

Conveyance: The process of moving water from one place to another.

Curbs: Concrete barriers on the edges of streets used to direct storm water runoff to an inlet or storm drain and to protect lawns and sidewalks from vehicles.

Curve Number: An index that represents the amount of runoff from the combined hydrologic effect of soil, land use, agricultural land treatment class, hydrologic condition, and antecedent soil moisture. Curve numbers have a range of 0 to 100.

Design Storm: A rainfall event of specific depth or intensity (i.e. 3.12 inches or 4.80 inches/hour) and return frequency (e.g., 1- year storm) that is used to calculate runoff volume and peak discharge rate.

Detain: To store and slowly release storm water runoff following precipitation by means of a surface depression or tank and an outlet structure. Detention structures are commonly used for pollutant removal, water storage, and peak flow reduction.

Developed Area: That portion of the site that has been cleared, graded or built-upon.

Dry Well: Small excavated trenches filled with stone to control and infiltrate runoff, usually from rooftops.

Evaporation: The change by which any substance is converted from a liquid state and carried off in vapor.

Evapotranspiration: The combination of evaporation and transpiration of water into the atmosphere from living plants and soil.

Filter Strip: Grass strips along roads or parking lots that remove pollutants from runoff as it passes through, allowing infiltration and velocity reduction.

Floodplain: An area adjacent to a stream or river where water overflows its banks during high flow events.

Ground Water: The supply of fresh water found beneath the earth's surface (usually in aquifers) that provides base flow to streams and rivers and is often used for supplying wells and springs. The inflow to a ground water reservoir is called ground water recharge.

Gutter: The edge of a street (below the curb) designed to drain water runoff from streets, driveways, parking lots, etc. into catch basins and storm drains.

Huntersville Water Quality Design Manual: The document that contains the approved BMP designs and other information necessary for compliance with this Ordinance. The Huntersville Water Quality Design Manual shall be approved for use in the Town of Huntersville by the North Carolina Department of Environment and Natural Resources and shall be at least as stringent as the storm water design manual approved for use in Phase II jurisdictions by the Department for the proper implementation of the requirements of the federal Phase II storm water program. All references herein to the Huntersville Water Quality Design Manual are to the latest published edition or revision.

Hydrograph: A graphic plot of changes in the flow of water or in the elevation of water level plotted against time.

Hydrologic Abstractions: Physical processes of interception of rainfall or overland storm water flow by vegetation, evaporation from land surfaces and upper soil layers, transpiration by plants, infiltration of water into soil surfaces, and storage of water in surface depressions.

Hydrologic Cycle (Water Cycle): The cycle of water movement from the atmosphere to the earth and back to the atmosphere through various processes.

Hydrologic Soil Group (HSG): See Soil Group definition.

Hydrology: The science dealing with the properties, distribution and circulation of water.

Impervious Surface: A surface that cannot be penetrated by water such as pavement or rock and prevents infiltration, thus generating runoff.

Integrated Management Practices (IMP): A LID practice or combination of practices that are the most effective and practicable (including technology, economic, and institutional considerations) means of controlling the pre-development site hydrology.

Level Spreader: An outlet designed to convert concentrated runoff to sheet flow and disperse it uniformly across a slope to prevent erosion.

Low Impact Development (LID) Approach: A technology-based system for managing urban storm water runoff that combines a hydrologically functional site design with pollution prevention measures to compensate for land development impacts on hydrology and water quality. To be effective, the LID Approach must be applied to every phase of site planning, design, development and post-construction control for the purpose of mimicking predevelopment site hydrology by storing, infiltrating, evaporating and detaining storm water runoff. Examples of the LID Approach include reducing impervious surfaces, managing storm water closer to the source and avoiding large centralized management devices, phased grading, and vegetated conveyances instead of storm drain piping.

Low Impact Development (LID) BMPs: Decentralized, structural storm water treatment devices that utilize infiltration, evaporation, retention and detention as well as biological and physical processes to more closely replicate pre-development hydrology characteristics and reduce negative water quality impacts. Examples of LID BMPs include bioretention systems, sand filters with LID design, and vegetated filter strips.

Mecklenburg County Land Use & Environmental Services Agency (LUESA): The department or division of Mecklenburg County government (regardless of the title given to it by Mecklenburg County) which has responsibility for storm water and water quality matters, acting as the agent of the Town of Huntersville for various purposes in connection with the enforcement of the Huntersville Post-Construction Ordinance.

National Pollution Discharge Elimination System (NPDES) Permit: A permit issued pursuant to the federal Clean Water Act for the purpose of controlling discharges of pollutants to surface waters and protecting water quality. In North Carolina, NPDES Permits are issued by the N.C. Department of Environment and Natural Resources.

Nonpoint Source (NPS) Pollution: Forms of pollution caused by sediment, nutrients, organic and toxic substances originating from land use activities, which are carried to lakes and streams by surface runoff. Nonpoint source pollution occurs when the rate of materials entering these waterbodies exceeds natural levels.

Permeability: The property of a soil to transmit water under a gradient. It is measured by the quantity of water passing through a unit cross section, in a unit time, under a hydraulic gradient.

Pollutant Load: A calculated quantity that is the result of a flow rate and pollutant concentration applied over a given amount of time.

Rain Barrels: Barrels designed to collect and store rooftop runoff.

Receiving Waters: A river, ocean, stream, or other watercourse into which runoff from precipitation is discharged.

Recharge: The addition of water into the ground water via the surface of the ground.

Retain: To capture and hold storm water runoff following precipitation by means of a surface depression allowing the water to infiltrate into the soil, evaporate and possibly transporate thus reducing the hydrologic and pollution impacts downstream. Retention structures are commonly used for pollutant removal, water storage, and peak flow reduction.

Riprap: A facing layer (protective cover) of stones placed to prevent erosion or the sloughing off of a structure or embankment of a waterbody.

Runoff: Water from a precipitation event that flows across the ground surface. Run-off carries nonpoint source pollutants to receiving streams.

Sediment: The layer of soil, sand and minerals at the bottom of surface water, such as streams, lakes, and rivers that may absorb contaminants.

Sedimentation: The removal, transport, and deposition of detached soil particles by flowing water or wind.

Siltation: The deposition of finely divided soil and rock particles upon the bottom of a waterbody.

Site Fingerprinting: A development approach that places land disturbing activities away from environmentally sensitive areas (wetlands, steep slopes, etc.), future open spaces, tree save areas, future restoration areas, and temporary and permanent vegetative forest buffer zones. Ground disturbance is confined to areas where structures, roads, and rights-of-ways will exist after construction is completed.

Soil Group: Hydrologic Soil Groups (HSG) are used to estimate runoff from precipitation. Soils not protected by vegetation are placed in one of four (4) groups on the basis of the intake of water (infiltration) after the soils have been wetted and have received precipitation from long duration storms. Group A soils have a high infiltration rate and usually include course sand and gravel. Group B soils have a moderate infiltration rate and include soils with moderately fine to coarse texture. Group C soils have a slow infiltration rate and include soils that have a moderately fine to fine texture. Group D soils have a very slow infiltration rate and include fine textured clays (Soil Conservation Service, 1986).

Soil Moisture: Water diffused in the soil. It is found in the upper part of the zone of aeration where water is discharged by transpiration from plants or by soil evaporation.

Storm Water: Water that runs across the surface of the ground during and after precipitation events.

Storm Water Administrator: The Mecklenburg County Water Quality Program Manager that has been designated by the Town of Huntersville Board of Commissioners to administer and enforce the Huntersville Post-Construction Ordinance.

Storm Water Management Permit: A permit required for all development and redevelopment unless exempt pursuant to the Huntersville Post-Construction Ordinance, which demonstrates compliance with the Ordinance.

Swale: An open depression or wide, shallow ditch that intermittently contains or conveys runoff. Can be used as a BMP to detain and filter runoff.

Time of Concentration (Tc): The time required for runoff to travel from the hydraulically most distant point (in time) in the watershed, to the point of interest in the watershed.

Total Phosphorus (TP): A nutrient that is essential to the growth of organisms but when it occurs in high enough concentrations it can negatively impact water quality conditions. Total phosphorus includes both dissolved and suspended forms of reactive phosphorus, acid hydrolysable phosphorus and organic phosphorus as measured by Standard Method 4500-P.

Total Suspended Solids (TSS): Total suspended matter in water which includes particles collected on a filter with a pore size of 2 microns as measured by Standard Method 2540-D, which is commonly expressed as a concentration in terms of milligrams per liter (mg/l) or parts per million (ppm).

Travel Time (Tt): The time it takes water to travel from one location to another in a watershed. It is a component of the time of concentration (Tc).

Treatment Train: A series of BMPs or natural features, each designated to treat runoff that are implemented together to maximize pollutant removal effectiveness.

Water Table: The upper surface of a zone of saturation or ground water.

Watershed: The area of land that contributes surface runoff to a waterbody.

Wet Pond: A BMP designed to detain urban runoff and always contain water.

Wetlands: An area (including swamp, marsh, bog, prairie pothole, or similar area) that is typically inundated or saturated by surface or groundwater at a frequency and duration sufficient to support the growth and regeneration of vegetation requiring an abundant water source.

Section 3. Performance Criteria

3.1 Performance Criteria Applicable to All Developments

All land development activities required to comply with the Huntersville Post-Construction Ordinance must at a minimum meet the following Performance Standards:

(1) Vegetated Conveyances. Storm water runoff from the development shall be transported from the development by vegetated conveyances to the maximum extent practicable.

(2) Built-Upon Area Setbacks. All built-upon area for development and redevelopment subject to the requirements of the Huntersville Post-Construction Ordinance shall be at a minimum of 30 feet landward of all perennial and intermittent surface waters. This built-upon area setback can be located within the water quality buffer area. A surface water shall be deemed present if the feature is approximately shown on either the most recent version of the soil survey map prepared by the Natural Resources Conservation Service of the United States Department of Agriculture or the most recent version of the 1:24,000 scale (7.5 minute) quadrangle topographic maps prepared by the United States Geologic Survey (USGS). An exception to this requirement shall be granted if one or more of the following is satisfied and documented:

   (a) Based on an on-site determination by the Storm Water Administrator, surface waters are not present on the site. When a landowner or other affected party believes that the maps have inaccurately depicted surface waters, he or she shall consult the Storm Water Administrator. Upon request, the Storm Water Administrator shall make on-site determinations. Surface waters that appear on the maps shall not be subject to the Huntersville Post-Construction Ordinance if this on-site determination shows that they fall into one of the following categories:
   - Ditches and manmade conveyances other than modified natural streams unless constructed for navigation or boat access.
   - Manmade ponds and lakes located outside natural drainage ways.
   - Ephemeral (storm water) streams.

   (b) Based on a Variance issued pursuant to Section 11.3 of the Huntersville's Zoning Ordinance, unnecessary hardships would result from the strict application of this requirement.

   (c) Based on a determination by the Storm Water Administrator, a lack of practical alternatives exists for accomplishing the basic propose of the project in a manner that would avoid or result in less adverse impact to surface waters considering the potential for a reduction in size, configuration, or density and all alternative designs.

(3) Stream Buffers. The S.W.I.M. Stream Buffer requirements as described in Section 8.25 of the Huntersville's Zoning Ordinance shall apply to low density projects

3.2 Performance Criteria Applicable to High Density Developments

Developments required to comply with the Huntersville Post-Construction Ordinance that have less than or equal to 12% built-upon area are called “Low Density” developments. These developments are required to comply with the criteria described in Section 3.1. Developments required to comply with the Huntersville Post-Construction Ordinance that have greater than 12% built-upon area are called “High Density” developments. These developments are required to comply with all the Performance Criteria specified in Section 3.1 as well as the following additional criteria. Tables 6.1 and 6.2 in Section 6 of this manual contain a description of approved BMPs for meeting each of these criteria.

1. All storm water treatment systems used to meet these Performance Criteria shall be designed to achieve average annual 85% Total Suspended Solids (TSS) removal for the developed area of a site. LID BMPs or a combination of LID and Conventional BMPs as described in the Tables 6.1 and 6.2 shall be used to meet these water quality Performance Criteria. If a combination of LID and Conventional BMPs is used, then at a minimum the first 50% of the runoff from the one (1) inch storm event must be treated using LID BMPs. The remaining 50% shall be treated using Conventional BMPs capable of achieving the above described pollutant removal efficiency. No one bioretention BMP shall exceed 5,000 square feet of soil media surface area.

2. LID BMPs or a combination of LID and Conventional BMPs shall be used to control and treat the increase in storm water runoff volume associated with post-construction conditions as compared with pre-construction (existing) conditions for the 2-year frequency, 24-hour duration storm event (3.12 inches) in the Rural and Transitional Zoning Districts. For all other Zoning Districts, LID practices or a combination of LID and Conventional BMPs shall be used to control and treat the increase in storm water runoff volume associated with post-construction conditions as compared with pre-construction (existing) conditions for the 1-year frequency, 24-hour duration storm event (2.58 inches).

3. Where any storm water BMP employs the use of a temporary water quality storage pool as a part of its treatment system, the drawdown time shall be a minimum of 48 hours and a maximum of 120 hours.

4. The peak storm water runoff release rates leaving the site during post-construction conditions shall be equal to or less than the pre-development peak storm water runoff release rates for the 2-year frequency, 24-hour duration storm event and 10-year frequency, 24-hour duration storm event. The emergency overflow and outlet works for any pond or wetland constructed as a storm water BMP shall be capable of safely passing a discharge with a minimum recurrence frequency of 50 years. For detention basins, the temporary storage capacity shall be restored within 72 hours. Requirements of the Dam Safety Act shall be met when applicable.

3.3 Mitigation Approved for Huntersville's Post-Construction Ordinance

3.3.1 Mitigation Options

The Huntersville Post-Construction Ordinance allows two (2) types of mitigation, including LID Mitigation for new developments with greater than or equal to 50% impervious area and Development and Redevelopment Mitigation. LID Mitigation allows a development to substitute Conventional BMPs for LID BMPs on the development site. Two (2) LID Mitigation options are available, including off-site and buy-down mitigation. Both options will result in the construction of retrofit projects in the same river basin (Catawba or Yadkin) as the development site for the purpose of removing the increased pollutants discharged to surface waters at the development site as a result of the use of Conventional instead of LID BMPs. Off-site mitigation requires the developer or their designee to construct and maintain the mitigation project. Buy-down mitigation requires the developer to provide funding to the jurisdiction toward the construction and maintenance of a mitigation project for up to 20 years. The methodologies for calculating the pollutant load required for off-site mitigation as well as the LID Buy-Down Mitigation Cost are described in Sections 3.3.2 and 3.3.4, respectively. These methodologies were selected as the best available approach for performing these calculations. Some of the values represented in these methodologies are not absolute; however, for the purpose intended they are considered adequate.

Two (2) Development and Redevelopment Mitigation options are available, including an option for lots less than one (1) acre that applies to the entire jurisdiction and an option for projects located in the Town Center Zoning District. Development and redevelopment projects on lots less than one (1) acre are allowed by right to forego meeting the requirements of the Huntersville Post-Construction Ordinance when mitigation requirements are fulfilled as described in Section 3.3.5, provided the following criteria are met:

1. The lot has been described by metes and bounds in a recorded deed or shown on a recorded plat prior to July 1, 2007;
2. Development and redevelopment on the lot are not part of a larger common plan of development or sale, even though multiple, separate or distinct activities take place at different times on different schedules;
3. Stream Buffer requirements are fulfilled as described in Section 8.25 of the Huntersville Post-Construction Ordinance; and

Redevelopment projects in the Town Center Zoning District are allowed by right to forego meeting the requirements of the Ordinance when mitigation requirements are fulfilled as described in Section 3.3.5, provided the stream buffer requirements are fulfilled. If there is no net increase in existing built-upon area, including built-upon area that is removed as part of the redevelopment, and there is no decrease in existing storm water controls, then there is no limit on the amount of disturbed area. If either of these provisions is not satisfied, then the amount of total disturbed area on the site must be less than one (1) acre. These provisions exist to ensure compliance with minimum State requirements for post-construction storm water controls.

3.3.2 Pollutant Load Required for LID Mitigation

The Huntersville Post-Construction Ordinance requires that all BMPs be designed to achieve an average annual 85% Total Suspended Solids (TSS) removal for the first one (1) inch of rainfall from the developed area of the site. LID BMPs or a combination of LID and Conventional BMPs can be used to meet this requirement. It is estimated that a combination of LID and Conventional BMPs will achieve an average annual 85% TSS and 60% Total Phosphorus (TP) removal efficiency whereas Conventional BMPs alone achieve an estimated 85% TSS and 50% TP removal efficiency. For both mitigation options, a Conventional BMP must be constructed on the development site and mitigation must be provided to achieve a net mass removal of TP greater than or equal to the TP load associated with the difference between LID versus Conventional BMPs at the development site treating runoff from the first one (1) inch of rainfall. As described above, this is the difference between 60% and 50% TP removal, which is 10%. To calculate the TP load associated with this 10% removal efficiency, identify the TP load in lbs./acre/year associated with the land use applicable to the development site in Table 3.1 below. If a combination of land uses exists at the development site, use the land use from the table that has the highest pollutant load.

_Table 3.1. TP Loading Rates for Selected Land Uses

Land Use	TP Load (lb./ac/year)
Multi-Family High (70% impervious)	1.83
Commercial – High (85% impervious)	2.85
Office-Industrial High (70% impervious)	1.86
Industrial (65% impervious)	2.39
Mixed Use (60% impervious)	2.24
High Density Mixed Use (70% impervious)	2.49
Ultra-Mixed Use (90% impervious)	2.97

The TP load associated with the applicable land use for the development site from Table 3.1 is multiplied by the total number of acres for the site to obtain a total TP load for the site. This total TP load is then multiplied by 10% to obtain the pollutant load required for mitigation. Table 3.2 below provides an example calculation for a one acre ultra-mixed use development.

Table 3.2**.** Example Pollutant Load Calculations for One Acre Ultra Mixed Use Development

1	Onsite Drainage Area	1.00 acre
2	Total Phosphorus Loading (select value from Table 3.1)	2.97 lbs./acre/yr.
3	Total Phosphorus Loading for the Site (Row 1 x Row 2)	2.97 lbs./year
4	**Pollutant Load Required for Mitigation (Row 3 x 10%)**	**0.297 lbs.**

3.3.3 Criteria for Off-Site LID Mitigation Option

The Storm Water Administrator shall receive, review, approve, disapprove or approve with conditions an "Application for LID Mitigation" with the Off-Site Mitigation Option selected. This application is provided in Appendix F. The application shall be submitted for review along with the Concept Plan Application. It is further required that a legally valid instrument be attached to the application form demonstrating that the applicant has legal title to the property. A Phase I environmental site assessment must also be attached identifying areas of concern on or immediately adjacent to the site. At the discretion of the Storm Water Administrator, the requirement for a Phase I environmental site assessment may be waived. An Operation and Maintenance Agreement and Maintenance Plan must be attached to the application form for each BMP included in the mitigation project. The criteria for approval of an Application for LID Mitigation using the Off-Site Mitigation Option are provided below. Failure to satisfy these conditions will result in disapproval and at the discretion of the Storm Water Administrator approval can be granted with specific conditions attached.

1. Conventional BMP(s) shall be designed, constructed, and maintained on the development site to achieve an average annual 85% Total Suspended Solids (TSS) removal for the developed area of the site in accordance with the criteria and specifications in the Huntersville Water Quality Design Manual;
2. The development site shall achieve full compliance with the Performance Criteria contained in Section 8.17.12(b) 1, 2, 3, 5, 6, and 7 of the Huntersville Post-Construction Ordinance;
3. LID BMP(s) shall be designed, constructed, and maintained on property other than the development site to at a minimum achieve the pollutant load required for mitigation (see Section 3.3.2) using the methodology described in Table 3.3;
4. BMP(s) shall be sized for the corresponding watershed area according to the design standards in the Huntersville Water Quality Design Manual;
5. BMP(s) shall be inspected by the Storm Water Administrator and found to be in compliance with all approved plans and specifications prior to the release of occupancy permits for the development site; and
6. All off-site mitigation BMPs shall be subject to the maintenance requirements as well as installation and maintenance performance securities specified in the Huntersville Post-Construction Ordinance and the Administrative Manual.

Table 3.3. Example Calculations for Showing TP Reduction from Off-Site BMP

1	Project Site Drainage Area (acres)	
2	Phosphorus Loading at Project Site (lbs./acre/year) (select value from Table 3.1)	
3	Total Phosphorus Loading at Project Site (lbs./year) (Row 1 x Row 2)	
4	Pollutant Load Required for Mitigation (lbs./year) (Row 3 x 10%)	
6	Mitigation Site Drainage Area (acres)	
7	Phosphorus Loading at Mitigation Site (lbs./acre/year) (select value from Table 3.1)	
8	Total Phosphorus Loading at Mitigation Site (lbs./year) (Row 6 x Row 7)	
9	Total Phosphorus Removal Efficiency of BMP at Mitigation Site (%)	
10	Total Phosphorus Loading Reduced by Mitigation Site (lbs./year) (Row 8 x Row 9)	
11	**Pollutant Load Mitigated (%) ((Row 10 / Row 4) x 100)**	

3.3.4 Criteria for Buy-Down LID Mitigation Option

The LID Buy-Down Mitigation Cost was based on the estimated cost for the construction, maintenance and administration of an LID BMP (bioretention system) over its anticipated 20 year life span that is designed to remove the pollutant load required for mitigation as described in Section 3.3.2 for an ultra-mixed use development at 90% impervious. This example was selected because it represents the highest LID construction, maintenance and administrative costs that will occur in the Town of Huntersville. It is important to note that the cost for the land necessary to construct the bioretention system is not included in this calculation. For this analysis, it was estimated that a one acre ultra-mixed use development at 90% impervious (see Table 3.1) would generate 2,793.6 ft^3 of runoff from a one (1) inch rain event (required design storm), which established the water quality volume or Wave. The Huntersville Post-Construction Ordinance requires that the first 50% of this runoff be treated with a bioretention system or other LID measure, which equates to a volume of 1,396.8 ft^3. Based on the standard in the N.C. BMP Design Manual, 1,397 ft^2 of bioretention area would be required to treat this volume. The cost to construct bioretention in Mecklenburg County is estimated at $9.60/$ft^2$. The extended cost to construct 1,397 ft^2 of bioretention area is $13,411.20. Table 3.4 summarizes these calculations.

Table 3.4. Cost for Construction of Bioretention System for One Acre Ultra Mixed Use Development

1	Wave generated by 1 acre ultra-mixed use development	2,793.6 ft^3
2	Volume to be treated by bioretention (Row 1 x 50%)	1,397 ft^3
3	Area of bioretention needed to treat 50% of Wave (from N.C. BMP Design Manual)	1,397 ft^2
4	Estimated cost/ft^2 to construct bioretention (estimated from Mecklenburg County construction costs)	$9.60/$ft^2$
5	**Total Cost (Row 4 x Row 3)**	**$13,411.20**

Operation and maintenance costs at a rate of $4,400/acre and administrative costs at a rate of 12% of the total project cost are added to the construction cost from Table 3.4 to determine the LID Buy-Down Mitigation Cost for a one (1) acre ultra-mixed use development. Calculations are illustrated in Table 3.5.

Table 3.5. LID Buy-Down Cost for a One Acre Ultra Mixed Use Development

1	Pollutant Load Required for Mitigation (see Table 3.2)	0.297 lbs.
2	Pollutant Load Required for Mitigation for the 20 Year Life Span of the BMP (Row 1 x 20)	5.94 lbs.
3	Pollutant Load Over 20 Years x Mitigation Rate (cost necessary to recoup construction costs from Table 3.4) (Row 2 x $2,257.78)	$13,411.21
4	20 Year Operation and Maintenance Costs at $4,400/Acre	$4,400.00
5	Administrative Costs at 12% of Total ((Rows 3 + 4) x 0.12)	$2,137.35
6	**Total LID Buy-Down Mitigation Cost (Rows 3 + 4 + 5)**	**$19,948.56**

From the above calculations, the rates contained in Table 3.6 are set for the calculation of the LID Buy-Down Mitigation Cost.

Table 3.6. Fixed Rates for Calculating LID Buy-Down Mitigation Costs

Buy Down Rate (multiply times the Pollutant Load Required for Mitigation for the 20 Year Life Span of a BMP)	$2,257.78
Operation and Maintenance Cost	$4,400/acre
Administrative Cost	12% of total

Table 3.7 sets the LID Buy-Down Mitigation Costs per acre for select land uses based off the TP loading rates from Table 3.1 and the fixed rates from Table 3.6.

Table 3.7. Huntersville LID Buy-Down Cost per Acre for Select Land Uses

Land Use	TP Load (lb./ac/year)	LID Buy-Down Cost/Acre
Multi-Family High (70% impervious)	1.83	$14,183.09
Office-Industrial High (70% impervious)	1.86	$14,334.81
Mixed Use (60% impervious)	2.24	$16,256.64
Industrial (65% impervious)	2.39	$17,015.25
High Density Mixed Use (70% impervious)	2.49	$17,520.99
Commercial – High (85% impervious)	2.85	$19,341.67
Ultra-Mixed Use (90% impervious)	2.97	$19,948.56

The process for requesting approval of an LID Buy-Down Mitigation Option for a proposed development begins with the submittal to the Storm Water Administrator of an "Application for LID Mitigation" with the Buy-Down Mitigation Option selected. This application is provided in Appendix F. The application shall be submitted for review along with the Concept Plan Application. The Storm Water Administrator shall consider the information provided in the application and approve, disapprove or approve with conditions. The criteria for approval of an Application for LID Mitigation using the Buy-Down Mitigation Option are provided below. Failure to satisfy these conditions will result in disapproval and at the discretion of the Storm Water Administrator approval can be granted with specific conditions attached.

1. Projects and/or properties shall be available for mitigation at the time the "Application for LID Mitigation" is received;
2. Conventional BMP(s) shall be designed, constructed, and maintained on the development site to achieve an average annual 85% Total Suspended Solids (TSS) removal for the developed area of the site in accordance with the criteria and specifications in the Huntersville Water Quality Design Manual;
3. The development site shall achieve full compliance with the Performance Criteria contained in Section 8.17.12(b) 1, 2, 3, 5, 6, and 7 of the Huntersville Post-Construction Ordinance; and
4. Payment shall be made to the Town of Huntersville prior to the issuance of the Storm Water Management Permit based on the developments predominant land use and the associated LID Buy-Down Cost per acre illustrated in Table 3.7. On a case-by-case basis, the Storm Water Administrator may allow an LID Buy-Down Cost to be calculated for a unique land use using the formula in Table 3.5 and forgo the use of the established costs provided in Table 3.7. However, this calculation will be based on the TP loading rates established by the Storm Water Administrator for this unique land use and not the rates contained in Table 3.1.

The Town of Huntersville shall use money accrued through buy-down mitigation payments to install structural BMPs and/or perform stream restoration projects. The Storm Water Administrator has the discretion to allow buy-down mitigation payments to be applied to other projects. All projects paid for with buy-down mitigation funds shall be designed and installed to remove a pollutant load equal to or greater than the increased load allowed to discharge from the development site as a result of the mitigation option. Projects should occur in the same watershed (Yadkin or Catawba) as the development that was allowed the mitigation option to the extent practicable as determined by the Storm Water Administrator. There is no time constraint for the Town of Huntersville to spend mitigation money; however, the Town shall strive to spend buy-down monies in a timely and efficient manner such that a net improvement in water quality results. In addition, all projects constructed by the Town of Huntersville as part of this mitigation option shall be maintained by the Town of Huntersville or its designee into perpetuity.

3.3.5 Criteria for Development and Redevelopment Mitigation Options

One (1) of the following three (3) criteria must be fulfilled to satisfy the mitigation requirement for development and redevelopment projects on less than one (1) acre and for redevelopment in the Town Center Zoning District as described in Section 3.3.1:

1. Storm Water Quality Treatment requirements met on site as described in Section 8.17.12(b)(3), (4) and (5) of the Ordinance with LID or Conventional BMPs allowed;
2. Storm Water Volume and Peak Control requirements met on site as described in Section 8.17.12(b)(6) and (7) of the Ordinance; or
3. The Town is paid a mitigation fee prorated at $60,000 per acre for all projects except single-family residential that will be prorated at $45,000 per acre for the untreated post-project built-upon-area. This fee shall be used to cover the cost for installation by the Town or its designee of a mitigation project(s) capable of achieving a net mass removal of pollutants greater than or equal to the pollutant removal that would have been achieved by BMPs installed at the development site in full compliance with Ordinance requirements. The mitigation project(s), as determined by the Town, must be located in the same named lake or stream watershed that is receiving storm water discharge from the development site, including Lake Norman, Mountain Island Lake, McDowell Creek, Gar Creek, Ramah Creek, and Clarke Creek. An exception can be made if the Storm Water Administrator determines there are no viable mitigation projects in that watershed.

3.3.6 Administration

The Storm Water Administrator or designee is responsible for approving and tracking all Mitigation Applications as well as working with the Town of Huntersville to spend the monies received on viable water quality projects that comply with the intent of the Ordinance. Mitigation Applications are available on the following website: http://stormwater.charmeck.org (select "Regulations," Select "Huntersville," select "Post-Construction (PCSO)," select "Post-Construction Stormwater Management Permit Forms," select "Huntersville Mitigation Form"). The application must be completed in full and all applicable plans, calculations and documents described on page 2 must be attached before the application will be considered complete and accepted for review. Applications should be submitted at the time Concept Plans are submitted for review. All Mitigation Applications received will be issued an application/permit number that consists of the year followed by a number issued chronologically as follows: 2017-1; 2017-2; 2017-3. Application approval will occur in conjunction with the Concept Plan review and approval process.

Section 4. Low Impact Development Site Planning

4.1 Introduction

This Section focuses on the LID planning strategies and techniques that can be used in the development of the Concept Plan for achieving the Performance Criteria described in Section 3. The goal of LID site planning is to allow for the maximum reasonable utilization of the property while maintaining the pre-development hydrologic regime (volume, peak runoff rate for a given frequency). The LID approach combines a hydrologically functional site design with pollution prevention measures (BMPs) to reduce development impacts on hydrology and water quality. The goal is to maintain the pre-development storm water runoff volume, peak runoff rates, and to mimic pre-development runoff conditions. Storm water is managed in small, source control landscape features rather than in large, end-of-pipe pond structures located at the downstream extent of drainage areas. However, ponds may be required in addition to LID BMPs to create a "treatment train" affect designed to meet the Performance Criteria described in Section 3. Through LID, hydrologic functions such as infiltration, peak and volume of discharges, and ground water recharge can be maintained with the use of reduced impervious surfaces, functional grading, open channel sections, disconnection and utilization of runoff, and the use of bioretention/filtration landscape areas.

4.2 LID Goals

The goal of LID is to develop site design techniques, strategies, BMPs, and criteria to store, infiltrate, evaporate, transpire, retain, and detain runoff on the site to replicate pre-development runoff characteristics and mimic the natural and unique hydrology of the site. Since every aspect of site development affects the hydrologic response of the site, LID runoff control techniques also can address every aspect of site development. There is a wide array of impact reduction and site design techniques that allow the site designer to create storm water control mechanisms that function in a similar manner to natural control mechanisms. The net result will be to mimic the watershed's natural hydrologic functions or water balance between runoff, infiltration, storage, ground water recharge, and evapotranspiration. With the LID approach, receiving waters experience little change in the volume, frequency, or quality of runoff or in the base flows fed by ground water.

The goals of LID are discussed and demonstrated throughout this manual. The list below highlights and reinforces some of the main goals and principles of LID:

- Provide enhanced technology for environmental protection of receiving waters.
- Provide economic incentives to provide environmentally sensitive development.
- Develop the full potential of environmentally sensitive site planning and design.
- Encourage public education and participation in environmental protection.
- Reduce maintenance costs of the storm water infrastructure.
- Utilize concepts, technologies, and objectives for storm water management such as micromanagement and multi-functional landscape features (rain gardens, swales, and conservation areas) to mimic or replicate hydrologic functions, and maintain the ecological/biological integrity of receiving streams.

LID planning and techniques will reduce impervious areas, reduce the need for conventional pipe and pond technology, and reduce or limit clearing and grading. LID techniques integrate storm water controls throughout the site in small, discrete units. BMPs are distributed across each site, reducing the need for a centralized BMP.

4.3 Key Considerations for LID Site Planning

Examples of the LID site planning techniques include, but are not limited to:

- Maintaining natural drainage ways and patterns and directing runoff to depression areas.
- Preserving as many trees as possible, especially those located on soils with the highest permeability rates.
- Reducing the percentage of impervious area.
- Locating BMPs in soils with the highest permeability rates.
- Disconnecting impervious areas.
- Limiting clearing and grading in areas containing soils with the highest permeability rates.
- Locate impervious areas on less permeable soils.
- Maintaining existing natural topography and terrain. Avoid disturbance of, and construction in, steep slope areas (>15%).
- Limiting clear-cutting and mass-grading through “site fingerprinting” techniques. Selectively clear wooded lots to preserve the tree canopy, understory vegetation, and natural vegetative buffers. See Article 7 of the Huntersville Zoning Ordinance.
- Flattening slopes only within existing cleared and graded areas, where feasible, to facilitate on-lot storage and infiltration.
- Revegetating areas that have been cleared and graded.
- Dispersing storm water flow to the natural drainage ways rather than concentrating it in swales, pipes, or channels.

The appropriate combination of these techniques to maintain the curve number (CN) and time of concentration (Tc) will result in a design that maintains the pre-development runoff volume, peak rate, and frequency. The remainder of this Section offers guidance on how these and other LID site planning techniques can be used to achieve the LID hydrology and Performance Criteria (Section 3). The Section is divided into the four hydrologic components that are discussed in the hydrologic analysis:

- Minimizing development impacts on the existing CN (Section 4.4).
- Providing retention storage to maintain the CN (Section 4.5).
- Providing additional detention storage to maintain the CN (Section 4.6).
- Maintaining the Tc (Section 4.7).

4.4 Minimizing Impacts to the Curve Number (CN)

4.4.1 Introduction

The CN is used to determine the runoff volume from both the pre- and post-development condition. The aggregate CNs assigned to each area are used to arrive at a composite, or weighted, CN for the site watershed. As the CN from the pre-development condition to the post-development condition increases, storage is required to mimic the pre-development CN. Site development factors most responsible for the determination of the CN fall into four categories:

- Land cover type.
- Percentage and connectivity of impervious areas.
- Hydrologic conditions (good, fair, poor).
- Soil infiltration rate (HSG).

The evaluation and management of land cover type, and percentage and connectivity of impervious areas are different for LID and discussed in detail below.

4.4.2 Land Cover Type

The most important factor for the change in CN from the pre- to post-development condition is land cover. The land cover type is the distribution of the physical components of the site. It is typically a broad definition, such as residential ¼ acre lots, but can be defined in detail, such as trees in good, fair, or poor condition. For example, the land use might be low-density residential on an HSG B, which carries an average CN of 65 (see TR55 Table 2-2a, Soil Conservation Service, 1986); however, if examined more closely, each lot might incorporate LID site planning and retention practices that would effectively reduce the CN. Figure 4.1 illustrates a low-density residential lot that includes tree preservation, minimized impervious areas, and low-impact BMP retention and detention practices. As shown in Figure 4.1, the land cover of a site is directly affected by the extent of the limits of clearing and grading. To minimize these hydrologic impacts, LID site planning strategically reduces clearing and grading, preserves more trees wherever possible, and minimizes the percent and connectivity of impervious areas within a given drainage area. The designer should keep in mind that the change in the CN from pre- to post-development will directly affect the need for compensatory storm water storage volume; hence, reducing this change can potentially reduce the storage volume requirement, thereby increasing the reasonable use of the property.

Determining the existing land cover requires delineating the surface coverage of existing land cover features and sensitive areas such as woodlands, permeable soils, streams, floodplains, critical areas, wetlands, and steep slopes. Delineation of these areas is important for understanding existing site conditions and site hydrology. It should be noted that this process is exactly the same as the conventional site planning process. The difference is the increased amount of detail and effort required to calculate the CN.

Reduction in Land Cover Changes.
Reduction in land cover changes is the first step in maintaining existing CN. There are several ways to reduce land cover changes including:

- Reduce the size of cleared area (i.e., preserve as much woodland as possible) and increase reforestation areas.
- Locate cleared/graded areas outside permeable soils and vegetated areas.
- Design roads, sidewalks, and parking areas to minimize land cover impacts.
- Reduce or disconnect site imperviousness.

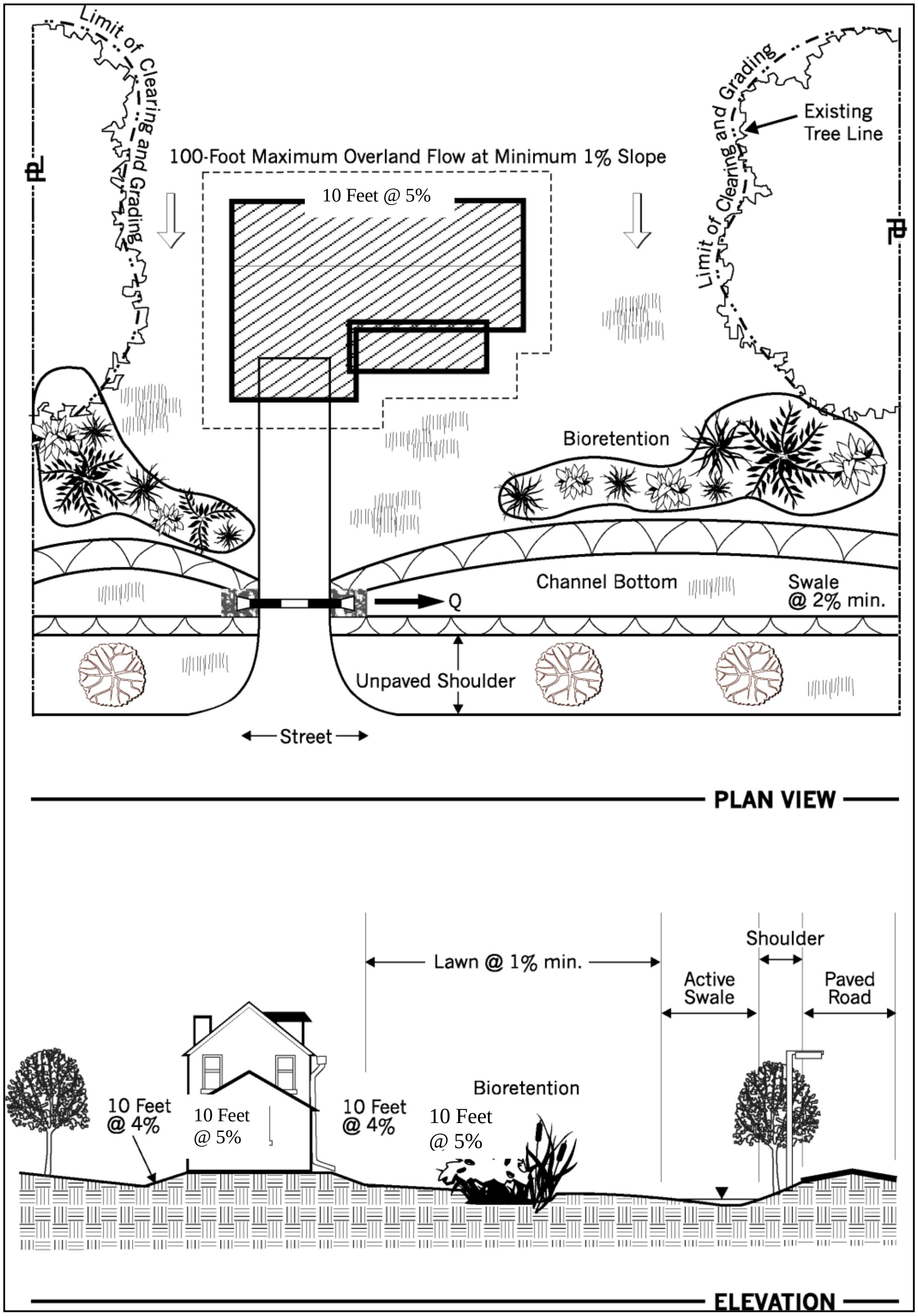


Figure 4.1. Schematic of Residential Single-Family Low Impact Lot Layout

Reduce Limits of Clearing and Grading.
The limits of clearing and grading refer to the site area to which development is directed. This development area will include all impervious areas such as roads, sidewalks, rooftops, and graded lawn areas and open drainage BMPs. To have minimal hydrologic impacts on existing site land cover (i.e., to reduce the percent change in the CN), the area of development should be located where the impact on the pre-development CN is less sensitive (e.g., developing barren C and D type soils will have a lesser hydrologic impact than developing forested A and B type soils). At a minimum, current requirements place the areas of development outside stream and lake buffer areas. Increasing these buffer areas, thereby reducing the limits of clearing and grading, will lead to a reduction in the percent change in the CN.

Site Fingerprinting.
Site fingerprinting (minimal disturbance techniques) can be used to further reduce the limits of clearing and grading, thereby minimizing the percent change in the CN. Site fingerprinting includes restricting ground disturbance by identifying the smallest possible area and clearly delineating it on the site. Land cover impacts can be minimized through minimal disturbance techniques that include the following:

- Minimizing the size of construction easements, materials storage areas, and siting stockpiles within the development envelope.
- Careful siting of lots and home layout, clearing and grading to avoid steep slopes, removing existing trees and excessive grading.
- Minimizing imperviousness by reducing paved surfaces on private areas.
- Homes on crawl spaces or basements that conform to natural grades without creating a flattened pad area for slab construction; thus saving clearing and grading costs.
- Flagging the smallest site disturbance area possible to minimize soil compaction on the site. Install orange construction fencing and tree protection areas where necessary to protect root structure along the limit of encroachment during the construction phase.
- Disconnecting all impervious areas to increase the Tc and flow paths.
- Re-vegetating cleared and graded areas to provide an effective way to decrease the post-development runoff CN. Sometimes it is impractical or impossible to develop a lot or group of lots using the minimal disturbance techniques. Re-vegetation can be used to connect bioretention facilities to natural drainage ways or to increase the size of riparian buffer areas. Re-vegetated areas also increase the permeability of the soil. In addition, these BMPs can add aesthetic value to a site.
- Maintaining existing topography and drainage patterns to encourage dispersed flow.

Locate Cleared and Graded Areas Outside Permeable Soils and Vegetated Areas.
Locating roadways, houses, and graded lawn areas within the following areas should be minimized as much as possible:
<u>Within pervious soils.</u> Sensitive soils for LID sites include soils with good infiltration characteristics. Site planning that locates impervious surfaces or directs compaction within areas of highly pervious soils creates the greatest possible change in infiltration between pre-development and post-development conditions. Areas that contain well-drained soils should be preserved. Preserving permeable soils should be promoted in all unpaved areas throughout the site, when considering optional ways to reduce the difference between the pre- and post-

development CNs. Maintaining permeable soils also helps maintain recharge areas for ground water and base stream flows.

Within existing vegetated areas. Protection of woodland areas can help to reduce impacts on existing land cover and associated CN. Expansion of protected vegetated areas adds to the benefits of reducing CN changes. Saving existing trees on a development site is a cost-effective and quality-enhancing practice. If the trees are appropriate for preservation and adequate protective measures are taken during construction, the preservation of existing trees on a site has many rewards. When these protected vegetated areas are combined with riparian buffers, they can provide added benefits of reduced storm water velocities, increased storm water infiltration, filtration of pollutants, protection of existing wildlife habitat, and stream bank and bed stability.

Use Alternative Roadway Designs.

Roadways, sidewalks, driveways, and parking areas are the greatest contributors to increasing the CN due to associated imperviousness and land clearing for cutting and filling. The primary considerations of road design are safety and balanced earthwork for the site. For LID sites, minimizing the effective imperviousness contributed by road and parking area pavement is also an important site planning and design consideration. In a LID layout, the roadway is designed to minimize hydrologic impacts by using minimal grading and clearing techniques and open drainage sections. LID roadway designs emphasize the need to keep paved areas to an absolute minimum. Reducing both pavement width and road length can help achieve this goal. The following features can be incorporated into the roadway to minimize impacts:

Narrow road sections. Small sections can be used to minimize site imperviousness and clearing and grading impacts.

Grassed swales and infiltration trenches. In Huntersville's Rural Zoning District, grassed swales and infiltration trenches can be used in place of curb and gutter in some circumstances (see Figure 4.2).

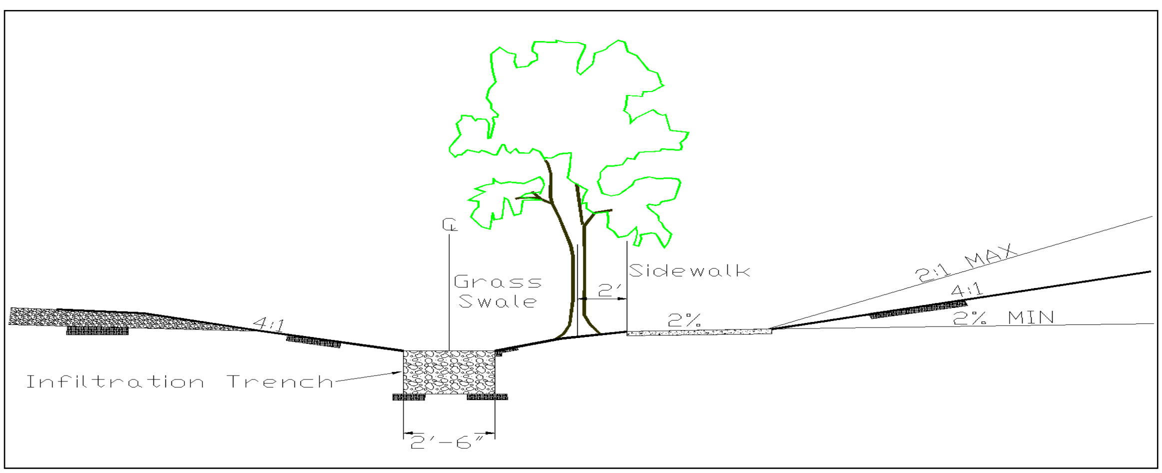


Figure 4.2. Grass Swale and Infiltration Trench

Curvilinear road layouts. Local and collector streets with curves and changes in alignment allow the flexibility to fit the road into the existing site topography. Following existing contours will minimize grading and make earthwork operations easier. It should be noted that curvilinear road layouts must meet current AASHTO design criteria.

Location of roads on ridges. Strategically locate the roadway entrance to minimize disturbance by positioning the entrance on the high point of the ingress, following mild contour slopes to the greatest degree possible. As an added benefit, following mild contour slopes when laying out roads allows reduction in cut and fill requirements and associated grading costs. It is also more aesthetically pleasing than rigid rectangular blocks.
Reduced application of sidewalks to one side of primary roads. Decrease site imperviousness by reducing sidewalk widths or by using alternate materials such as pervious pavers. The reduction of sidewalks to one of side of the street is allowed only in Huntersville's Rural Zone.

4.4.3 Reduction and Disconnection of Impervious Areas

By reducing and disconnecting site impervious areas, the amount of direct runoff can be significantly decreased. This requires careful planning. There must be adequate circulation so that pedestrians and vehicles do not use grassed areas and cause erosion. In turn, reduced widths and lengths result in reduction of associated infrastructure such as drainage pipes, etc.

Minimize rooftop imperviousness. Rooftops contribute to site imperviousness, and the number of lots per acre or lot coverage generally determines the site's rooftop impervious area. House type, shape, and size can affect rooftop imperviousness. As an example, more rooftop coverage is generally required for ranch-type homes that spread out square footage over one level. With this in mind, vertical construction is favored over horizontal layouts to achieve less impact.

Disconnect impervious areas. Reductions in post-development CNs can be gained by redirecting and dissipating concentrated flows from impervious areas onto vegetated surfaces. Strategies for accomplishing this include:

- disconnecting roof drains and directing flows to vegetated areas;
- directing flows from small swales to stabilized vegetated areas;
- breaking up flow directions from large paved surfaces; and
- encouraging sheet flow through vegetated areas.

Carefully locate impervious areas. To the extent possible, place impervious areas so that they drain to natural drainage features, vegetated buffers, natural resource areas, or permeable zones/soils. Additional LID site planning techniques aimed at reducing site imperviousness include:

- Using shared driveways in Water Supply Watershed Critical Areas. (Using shared driveways in other areas is recommended but may require a subdivision waiver. Shared driveways also need the approval of the Town of Huntersville.)
- Limiting residential driveway width to 9 feet (for both single and shared driveways).
- Minimizing building setback to reduce driveway lengths.
- Efficient parking lot layout. Avoid single loaded aisles, angled parking, and excessive spaces.
- Using private roads where possible to allow flexibility in reducing road widths (see Figure 4.2).
- Planning efficient lot layout to minimize the road length, single loaded streets and double frontage lots.

4.5 Providing Retention Storage to Maintain Existing CN

Once all of the appropriate strategies have been applied to the site to take advantage of infiltration and storage opportunities in the watershed, there still may be a need for additional retention storage to maintain the CN. The objective is to provide this additional storage as source control BMPs. These are small BMPs distributed strategically throughout the site and close to the origin of storm water runoff. When the need arises, additional detention storage basins may be required to maintain the pre-development peak runoff rate.

4.5.1 Residential Retention Storage

For residential LID sites, lot layouts must be planned to distribute retention storage volume as much as possible throughout the site. At the site planning stage, it is important to allocate enough area to provide for needed storm water retention storage. This involves developing a preliminary layout where LID techniques can be incorporated. At a minimum, this should include designating (1) road layout with potential LID geometric modifications, (2) sidewalk areas, (3) building footprint, driveway and accessory structures, and (4) potential BMP areas. When laying out the site, the designer should always keep in mind the four important factors that affect the change in pre- to post-development storm water runoff volume and peak rate including: land cover type, percentage and connectivity of impervious areas, hydrologic conditions, and soil type (HSG). The site should be planned to maximize lot yield while minimizing impacts on the hydrologic regime. Residential retention storage can be incorporated onto individual lots or common areas. Due to concerns with placement of easements on private residential lots and the future maintenance of these BMPs, locating them in common areas dispersed throughout the site is strongly encouraged. These BMPs should not be located on private residential lots.

Information and calculations provided in Section 5 can be used to determine the required retention storage area. Zoning requirements exist regarding maximum lot coverage in residential zones for various lot sizes in accordance with the Huntersville Zoning Ordinance. Lot coverage for residential zones relates to maximum impervious surface allowed per lot and can be used to determine available green space for on-lot retention storage area. Keep in mind the need for allowing “reasonable use” of a property and restrictions on locating storage areas within the building restriction line. Estimated requirements for retention storage areas (evenly dispersed throughout the development) can be compared with estimated available green space. In most cases, adequate space will be available to provide retention storage in zones. However, situations may arise for ½-acre lots and smaller where the magnitude of change in pre-development and post-development curve numbers results in storage requirements that cannot be fully accommodated while allowing reasonable use of lawn and/or open space area. Refer to Section 4.6 for more detailed information on this situation (i.e., incorporating more detention storage). This is important to realize when identifying the limits of clearing and grading on each lot. It may be necessary to minimize the clearing and grading to reduce changes in the CN to accommodate storage retention requirements. Terraces and enlarged drainage swales can also be used to provide additional detention storage as necessary.

4.5.2 Commercial/Industrial Retention Storage

Planning for retention storage volume for commercial and industrial LID sites is focused on two areas: perimeter buffer areas and green areas located within parking lots. On-site retention storage can be provided as interior bioretention, preferably located within the required landscape islands, or as cistern or rain barrel facilities. In the event that the available green space within the parking area is insufficient to provide for required storage volume (as computed in Section 5), additional space can be obtained by providing bioretention within the landscaped buffer area located on the perimeter of the commercial or industrial site (see Figure 4.3). For example, retention storage volume could be located within required commercial and industrial site setback areas or landscape buffers. Existing minimum green space requirements plus the size of perimeter buffers and parking space requirements will dictate the feasibility of providing all required storage within surface swales, terraces, or bioretention facilities (refer to the Huntersville Zoning Ordinance and the landscape details for specific requirements).

4.6 Methods for Additional Detention Storage

In some cases, it may be necessary to provide for additional detention storage to augment retention in maintaining the pre-development storm water runoff peak discharge rate. The following LID practices can be used for detention within residential or commercial/ industrial sites:

- swales with check dams;
- restricted drainage pipe and inlet entrances;
- wider swales and terraces;
- rain barrels;
- parking lot storage;
- rooftop storage; and
- diversion structures.

Additional planning considerations for swales include:

- Open drainage conveyance (swales or natural drainage ways) should be used to the extent allowed by existing ordinances. Terraces also can be designed for and used as detention. Drainage along primary roads must be contained in piped storm drains.
- Use 4:1 slopes for roadway swales out of the public right-of-way. These slopes, once graded, are to be stabilized with fiber mats or netting and then planted with perennials or wild flowers or dense ground cover or woody shrubs. The use of 4:1 slopes will minimize disturbance and preserve more existing trees. The slope of the graded swale to the building pad must be 1 percent minimum.
- Locate on-lot swale facilities where they can provide green space connection between existing wooded or natural areas.

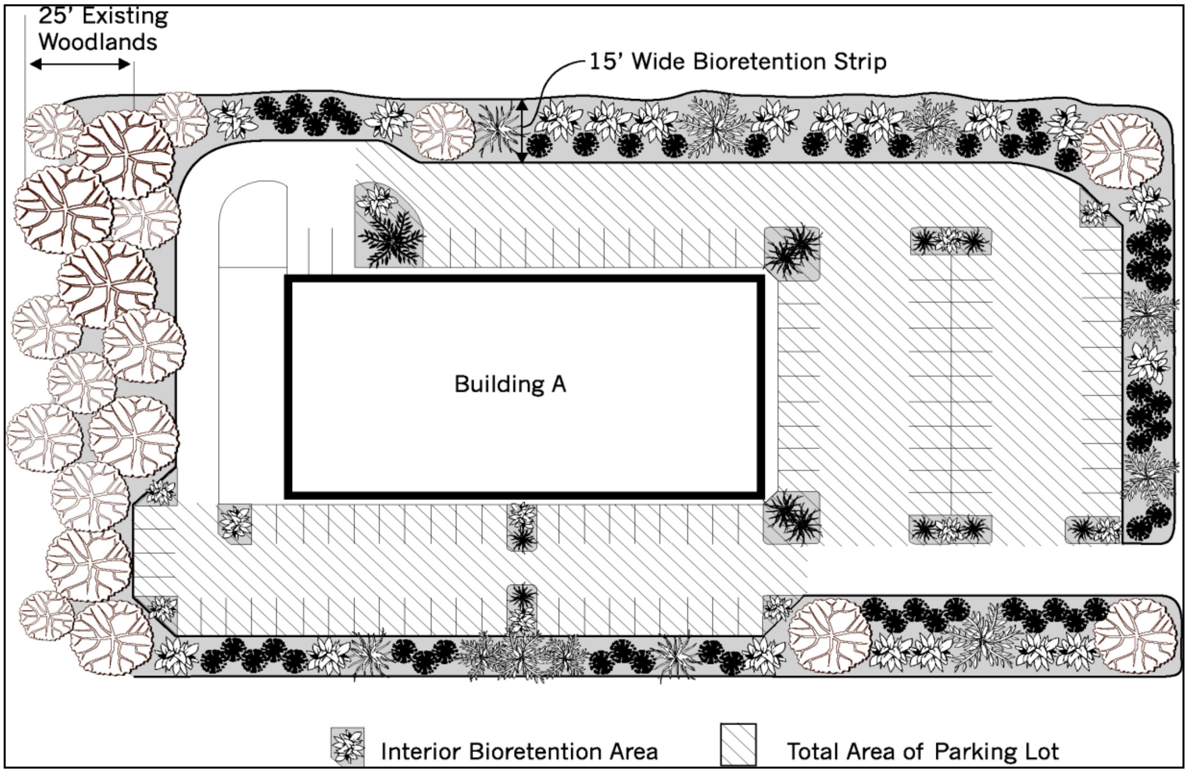


Figure 4.3. Providing Bioretention Within Landscaped Buffer Areas

4.7 Maintaining Existing Time of Concentration (Tc)

The time of concentration (Tc), in conjunction with the CN, determines the peak discharge rate for a storm event. From theoretical considerations, site and infrastructure components that affect time of concentration and travel time include:

- travel distance (flow path);
- slope of the ground surface and/or water surface;
- ground surface roughness; and
- channel shape and pattern.

These concepts are applied to LID by using techniques to control the Tc by modifying the following aspects of flow and conveyance within the development:

- maximize sheet flow;
- modify/lengthen flow path;
- site and lot slopes;
- open swale BMP; and
- site and lot vegetation.

Overland Sheet Flow. The site should be graded to maximize the overland sheet flow distance and to minimize disturbance of woodland along the Tc flow path. This practice will increase travel times thereby increasing the time of concentration and ultimately the peak discharge rate will be decreased. To provide sufficient contact time and allow for settlement of suspended solids, flow velocity in areas graded to natural drainage ways should not exceed 1 fps to the extent practicable. Install a stable, level spreader (timber tie, edging, etc.) along the upland edge of the natural drainage way buffer, or create a flat grassy area about 30 feet wide on the upland side of the buffer where runoff can spread out. This grassy area can be incorporated into the Upland Zone of the S.W.I.M. buffer; however, level spreaders must be located outside the buffer.

Flow Path. Increase flow path or travel distance of surface runoff to increase infiltration and travel time. One of the challenges of LID is to provide as much overland or sheet flow as possible to increase the time it takes for rooftop and driveway runoff to reach open swale drainage features or in some cases piped storm drains. Typically, the designer can perform one or both of two potential techniques for accomplishing this task. First, rooftop and driveway runoff can be permanently infiltrated or stored within infiltration trenches, dry wells, or cisterns strategically located to capture the runoff prior to it reaching the lawn. Second, strategic lot grading can increase both the surface roughness and the travel length of the runoff.

Site and lot slopes. Flatten lot slopes to approach a minimum 1 percent to increase infiltration and travel time**.** The building pad area is a 10-foot perimeter around the building with a positive drainage in accordance with the building code, or a minimum of five percent (5%) slope. Lot areas outside the building pad perimeter should contain a positive slope of at least 1 percent. As described in the Charlotte-Mecklenburg Storm Water Design Manual, the designer is responsible for ensuring that the slope of the lot does not cause flooding during the 100-year storm event. Soil compaction of original soils (not fill) in the lot area should be avoided to maximize the infiltration capacity of the soil. These infiltration areas can receive runoff from impervious surfaces such as rooftops and driveways to decrease travel times for these areas.

Open Swales. Wherever possible, LID aims to use open swales in lieu of more conventional storm drain structures**.** To alleviate flooding problems and reduce the need for conventional storm drain systems wherever possible vegetated or grassed open drainage BMPs should be provided as the primary means of conveying surface runoff between lots and along roadways. Lots should be graded so as to minimize the quantity and velocity of surface runoff within the open drainage BMPs. On-line infiltration BMPs and terraces can be used to reduce the quantity and travel time of the surface runoff as the need arises. At no time shall 5 cfs be exceeded.

Site and Lot Vegetation. Re-vegetate and/or plant graded areas to promote natural retention and increase travel time. Re-vegetating graded areas, planting, or better yet, preserving existing vegetation can reduce the peak discharge rate by creating added surface roughness as well as providing for additional retention and reducing the surface water runoff volume. Designers can connect vegetated buffer areas with existing vegetation or forest to gain retention/detention credit for runoff volume and peak rate reduction and to avoid "paved area" as the Tc flow path for the "shallow concentrated flow" part of the Tc calculation. The benefit of such practices will be to minimize the need for on-lot bioretention facilities.

Section 5. LID Hydrologic Analysis

5.1 Introduction

The purpose of this Section is to provide LID hydrologic analysis and computational procedures for use in determining LID storm water management requirements. Design concepts are illustrated by the use of runoff hydrographs that represent responses to both conventional and LID approaches. LID site planning and BMPs are defined and categorized into components of LID objectives. A strategy for using these LID techniques is provided in Section 4. The process for developing the LID hydrology is illustrated in Figure 5.1. This figure lists the sequential steps and the sections in the manual where the methods to calculate or determine the specific requirements are provided.

5.2 Hydrologic Comparison Between Conventional and LID Approaches

Conventional storm water conveyance systems are designed to collect, convey, and discharge runoff as efficiently as possible. Conventional storm water management BMPs are typically sited at the most downstream point of the entire site (end-of-pipe control). The storm water management requirement is usually to maintain the peak runoff rates at pre-development levels for a particular design storm event. Figure 5.2 illustrates the hydrologic response of the runoff hydrograph to conventional BMPs.

- Hydrograph 1 represents the response to a given storm of a site that is in a pre-development condition (e.g., woods, meadow). The hydrograph is defined by a gradual rise and fall of the peak discharge and volume.
- Hydrograph 2 represents the response of a post-development condition with no storm water management BMPs. This hydrograph definition reflects a shorter time of concentration (Tc) and higher runoff curve number (CN) than that of the pre-development condition, a rapid decrease in the time to reach the peak runoff rate, a significant increase in the peak runoff discharge rate and volume, and increased duration of the discharge volume.
- Hydrograph 3 represents a post-development condition with conventional storm water BMPs, such as a detention pond. Although the peak runoff rate is the same, the hydrograph exhibits significant increases in the runoff volume and duration of runoff from the pre-development condition.

In comparison with conventional storm water management, the objective of LID hydrologic design is to retain the post-development excess runoff volume in discrete units throughout the site to emulate the pre-development hydrologic regime. Management of both runoff volume and peak runoff rate is included in the design. The approach is to manage runoff at the source rather than at the end of pipe. Preserving the hydrologic regime of the pre-development condition requires both structural and nonstructural techniques to compensate for the hydrologic alterations of development. Typically alterations to the hydrologic regime as a result of development include, but are not limited to, the following:

- Increased runoff volume and velocity;
- Increased flow frequency, duration, and peak runoff rate;
- Reduced infiltration (ground water recharge);

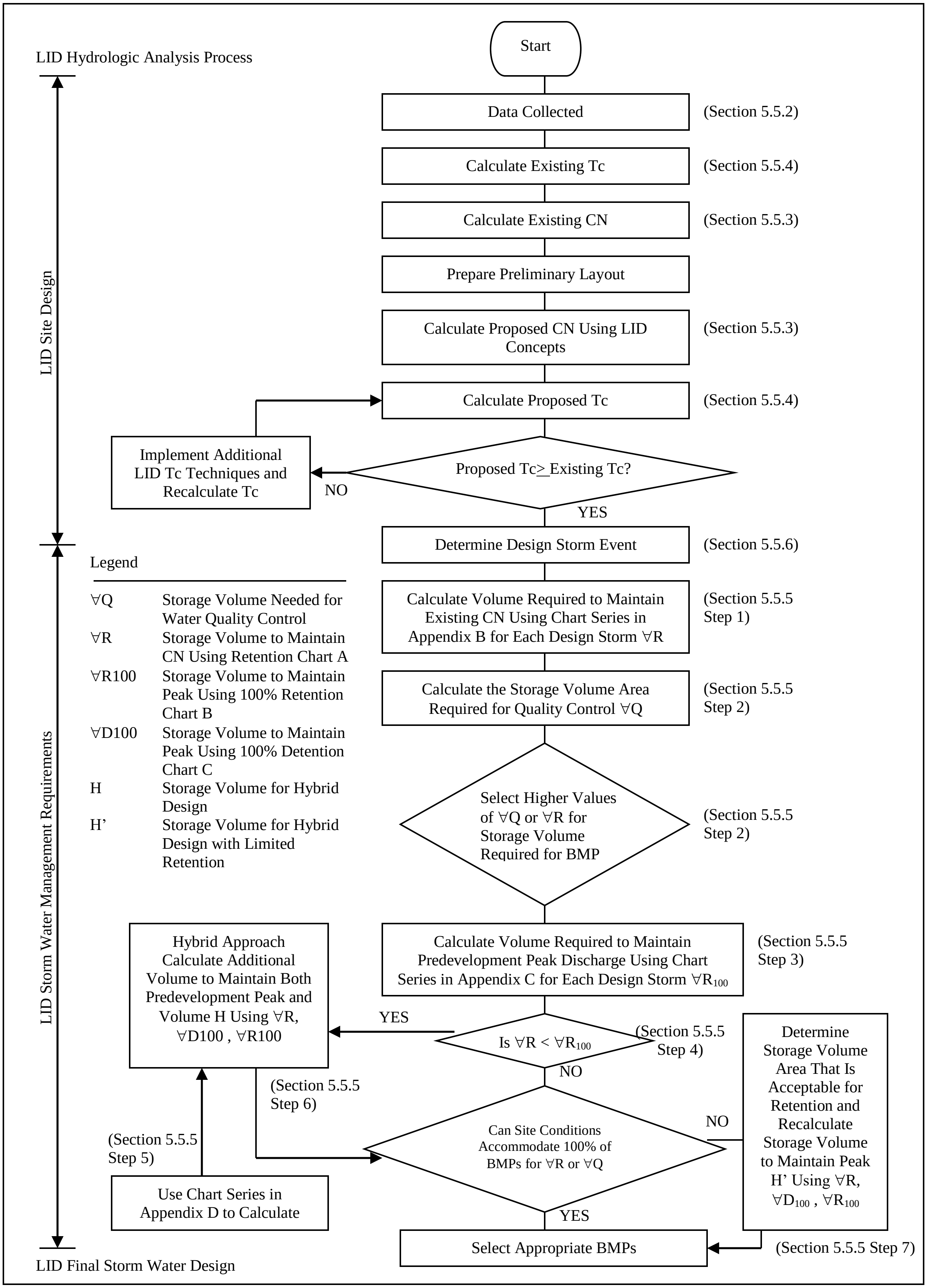


Figure 5.1. LID Analysis Procedure

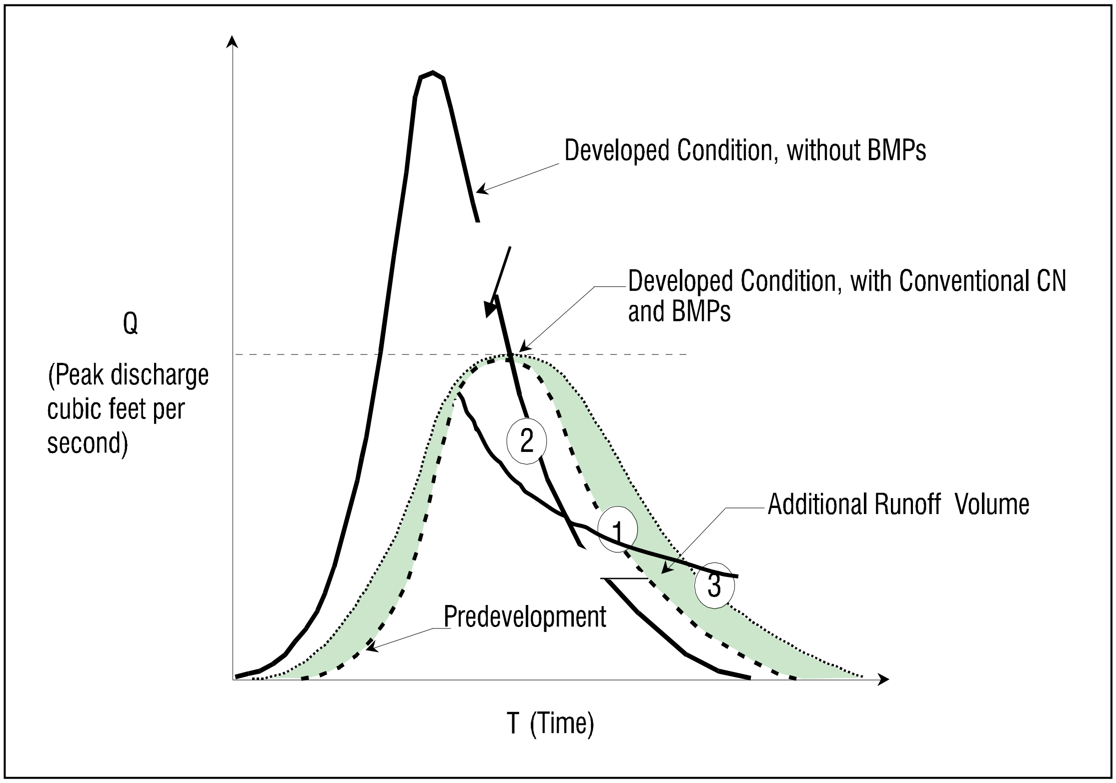


Figure 5.2. Hydrologic Response of Conventional BMPs

- Modification of the flow pattern;
- Faster time to peak, due to shorter Tc through storm drain features; and
- Loss of storage.

In LID, the design approach is to leave as many undisturbed areas as practicable to reduce runoff volume and runoff rates by maximizing infiltration capacity. Storm water management BMPs are then integrated throughout the site to compensate for the hydrologic alterations of development. The approach of maintaining areas of high infiltration and low runoff potential in combination with small, source control storm water management BMPs creates a "hydrologically functional landscape." This functional landscape not only helps maintain the pre-development hydrologic regime but also enhances the aesthetic and habitat value of the site. Figure 5.3 illustrates a comparison of LID and conventional BMPs:

- For hydrograph 1, refer to Figure 5.2 for description.
- For hydrograph 3, refer to Figure 5.2 for description.
- Hydrograph 4 represents the response of a post-development condition that incorporates LID storm water management. LID uses undisturbed areas and smaller retention storage areas distributed throughout the site (on-lot or in common areas) to reduce runoff volume. The peak runoff rate and volume remain the same as the pre-development condition through the use of common area or on-lot retention and/or detention. The frequency and duration of the runoff are also much closer to the existing condition than those typical of conventional BMPs.

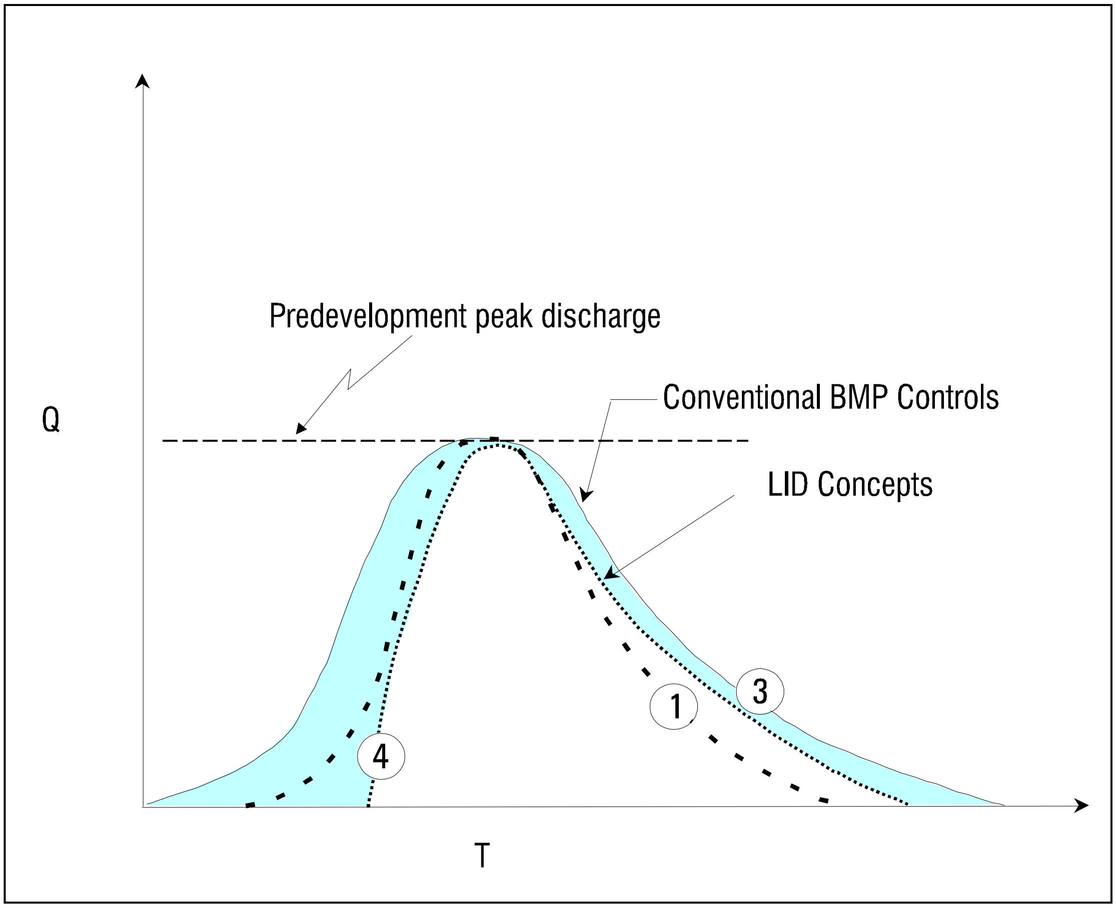


Figure 5.3. Comparison of the Hydrologic Response of Conventional and LID BMPs

5.3 Key LID Hydrologic Definitions

The LID "functional landscape" emulates the pre-development temporary storage (detention) and infiltration (retention) functions of the site. This functional landscape is designed to mimic the pre-development hydrologic conditions through runoff volume control, peak runoff rate control, flow frequency/duration control, and water quality control.

- Runoff Volume Control: The pre-development volume is maintained by a combination of minimizing the site disturbance from the pre-development to the post-development condition and then providing distributed retention BMPs. Retention BMPs are structures that retain the runoff for the design storm event. A "customized" or detailed CN evaluation is required to determine the required runoff volume. The storage required to maintain the pre-development volume may also be sufficient to maintain the pre-development peak rate. This storage volume determination is based on developed design charts and nomographs, which are included in the Appendices B, C, and D.
- Peak Runoff Rate Control: LID is designed to maintain the pre-development peak runoff discharge rate for the selected design storm events. This is done by maintaining the pre-development Tc and then using retention and/or detention BMPs (e.g., rain gardens, open drainage BMPs, etc.) that are distributed throughout the site. The goal is to first use retention practices to control runoff volume and, if these retention practices are not sufficient to

control the peak runoff rate, to then use additional detention practices to control the peak runoff rate. Detention is temporary storage that releases excess runoff at a controlled rate. The use of a combination of retention and detention to control the peak runoff rate is defined as the hybrid approach.
- Flow Frequency/Duration Control: Since LID is designed to emulate the pre-development hydrologic regime through both volume and peak runoff rate controls, the flow frequency and duration for the post-development conditions will be almost identical to those for the pre-development conditions (see Figure 5.3). Thus, the impacts on the sediment and erosion and stream habitat potential at downstream reaches can then be minimized.
- Water Quality Control: LID is designed to provide water quality treatment of runoff from the first 1 inch of rainfall using retention practices. Storm water treatment shall be designed to achieve average annual 85% Total Suspended Solids (TSS) removal and must apply to the volume of post-construction runoff. Drawdown time for this treated volume of runoff shall be a minimum of 2 days. The storage required for water quality control is compared to the storage required to control the increased runoff volume. The greater of the two volumes is the required retention storage. LID also provides pollution prevention by modifying human activities to reduce the introduction of pollutants into the environment. LID practices also aid in cooling runoff from developed sites thus lessening thermal peaks in receiving streams.

The low-impact analysis and design approach focuses on the following hydrologic analysis and design components:
- CN: Minimizing change in the post-development CN by reducing impervious areas and preserving more trees and meadows to reduce the storage requirements to maintain the pre-development runoff volume.
- Tc: Maintaining the pre-development Tc by minimizing the increase of the peak runoff rate after development by lengthening and flattening flow paths and reducing the length of the piped runoff conveyance systems.
- Retention: Providing retention storage for volume and peak control, as well as water quality control, to maintain the same storage volume as the pre-development condition.
- Detention: Providing additional detention storage, if required, to maintain the same peak runoff rate and/or prevent flooding and erosion downstream.

Table 5.1 provides a summary of LID techniques that affect these components.

5.4 Hydrologic Evaluation

The purpose of the hydrologic evaluation is to determine storm water management requirements for LID sites. The evaluation method is used to determine the amount of retention and/or detention to control the runoff volume and peak runoff rate. Appropriate detention and/or retention techniques are then selected to meet these requirements.

5.4.1 LID Runoff Curve Number (CN)

Calculation of the LID CN is based on a detailed evaluation of the existing and proposed land cover so that an accurate representation of the potential for runoff can be obtained. This calculation requires the designer to investigate key parameters associated with a LID:

Table 5.1. LID Techniques and Hydrologic Design and Analysis Components

	LID Technique															
Low-Impact Hydrologic Design and Analysis Components	Flatten slope	Increase flow path	Increase sheet flow	Increase roughness	Minimize disturbance	Flatten slopes on swales	Infiltration swales	Vegetative filter strips	Constricted Pipes	Disconnected impervious areas	Reduce curb and gutter	Rain barrels	Rooftop storage	Bioretention	Revegetation	Vegetation preservation
Lower Post-Development CN					☐		☐	☐		☐	☐			☐	☐	☐
Increase Tc	☐	☐	☐	☐		☐		☐	☐	☐	☐	☐	☐	☐	☐	☐
Retention							☐	☐				☐	☐	☐	☐	☐
Detention						☐			☐			☐	☐			

- Land cover type;
- Percentage of and connectivity of impervious areas;
- Hydrologic soils group (HSG); and
- Hydrologic condition (average moisture or runoff condition).

Comparing conventional and LID CN calculations, the conventional CNs are based on the land cover assumptions whereas the LID CN is based on a detailed evaluation of the land cover and parameters listed above. For example, as illustrated in Figure 5.4, customizing the CN for a LID site allows the developer/engineer to take advantage of and get credit for such LID site planning practices as the following:

- Narrower driveways and roads (minimizing impervious areas);
- Maximized tree preservation or re-forestation (tree planting);
- Site fingerprinting (minimal disturbance);
- Open drainage swales, sheet flow, maintain natural drainage patterns;
- Preservation of soils with high infiltration rates to reduce CN; and
- Location of BMPs on high infiltration soils.

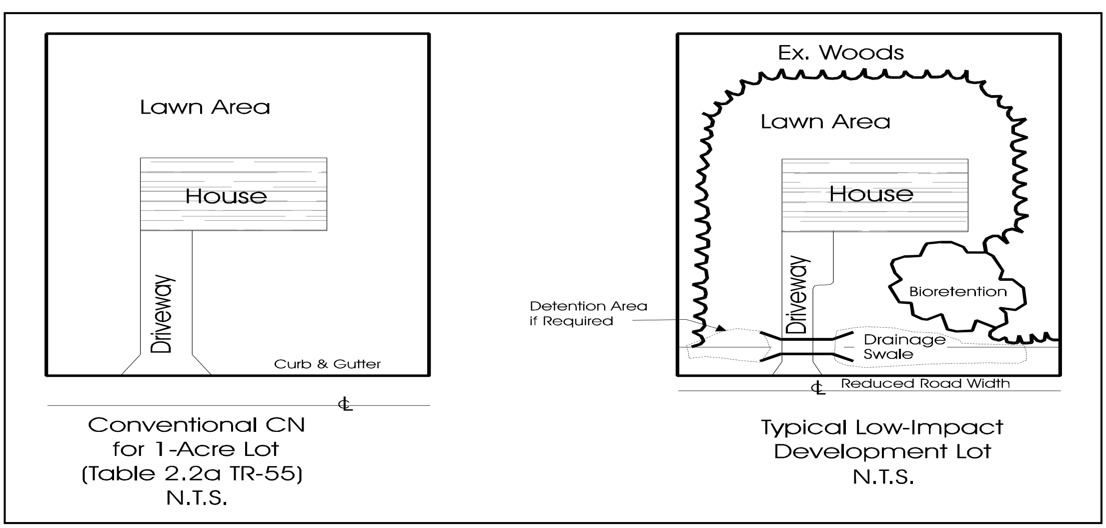


Figure 5.4. Comparison of Land Covers Between Conventional and LID CNs

Table 5.2 illustrates a comparison of LID CN land covers with those of a conventional CN for a typical 1-acre lot. Figure 5.4 illustrates a comparison of conventional CN land covers with a LID customized CN for a 1-acre lot.

Table 5.2. Comparison of Conventional and LID Land Covers

Conventional Land Covers (TR-55 Assumptions)	**LID Land Covers**
20% impervious 80% grass	15% imperviousness 25% woods 60% grass

Table 5.3 provides a list of LID site planning practices and their relationship to the components of the LID CN. Key LID techniques that will reduce the post development CN, and corresponding runoff volumes, are as follows:

- <u>Preservation of Permeable Soils:</u> This approach includes site planning techniques such as minimizing disturbance of soils, particularly vegetated areas with high infiltration rates. Additional planning should limit the placement of infrastructure and impervious areas such as houses, roads, and buildings on more permeable soils. These areas of permeable soils should be reserved for infiltration practices. Care must be taken when determining the suitability of soils for proposed construction practices. Adequate geotechnical information (in addition to County Soils Maps) is required for planning practices.

Table 5.3. LID Planning Techniques to Reduce the Post-Development LID CN

Suggested Options Affecting Curve Number	Limit use of sidewalks	Reduce road length and width	Reduce driveway length and width	Conserve natural resources areas	Minimize disturbance	Preserve permeable soils	Preserve natural depression areas	Use transition zones	Use vegetated swales	Provide for bioretention
Land Cover Type				□	□			□	□	□
Percent of Imperviousness	□	□	□					□		
Hydrologic Soils Group				□		□				
Hydrologic Condition				□	□	□				
Disconnecting Impervious Area	□	□	□							
Storage & Infiltration							□			□

- <u>Preservation of Existing Natural Vegetation:</u> Woods and other vegetated areas provide many opportunities for storage and infiltration of runoff. By maintaining the surface coverage to the greatest extent possible, the amount of compensatory storage for BMPs is minimized. Naturally vegetated areas also can be used to provide surface roughness, thereby increasing the Tc. In addition, plant life functions to filter out and uptake pollutants, particularly nitrogen, phosphorus and heavy metals.

- Minimization of Site Imperviousness: Reducing the amount of imperviousness on the site will have a significant impact on the amount of compensatory BMP storage required since there is almost a one-to-one corresponding relationship between rainfall and runoff for impervious areas.
- Disconnection of Site Imperviousness: Impervious areas are considered disconnected if they do not connect to a storm drain structure or other impervious areas through direct or shallow concentrated flow. Disconnecting and directing impervious areas to sheet flow onto vegetated or bioretention areas to allow for infiltration results in a direct reduction in runoff and corresponding storage volume requirements.
- Creation of Transition Zones and Bioretention: Transition zones are vegetated areas that can be used to store and infiltrate runoff from impervious areas before they discharge from the site. These areas are located at the sheet or discharge points from graded and impervious areas. These areas affect the land cover type calculations of the LID CN.

The use of these techniques can provide cost savings to the overall site development and infrastructure. Figure 5.5 illustrates the hydrologic response using LID to reduce impervious area and increase the storage volume.

- For hydrograph 1, refer to Figure 5.2 for description.
- For hydrograph 2, refer to Figure 5.2 for description.

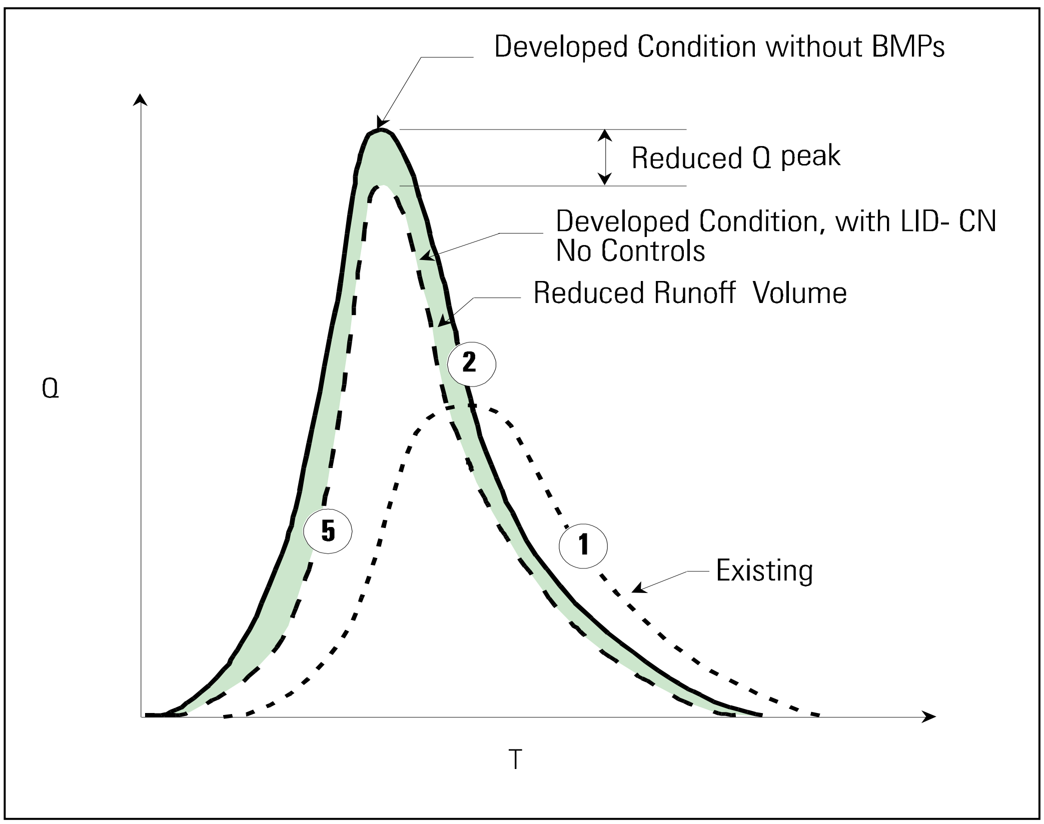


Figure 5.5. Effect of LID CN on the Post-Development Hydrograph Without BMPs

- Hydrograph 5 represents the resulting post-development hydrograph using the LID CN only. There is a reduction in both the post-development peak rate and volume. Section 5.5.3 describes the process and computational procedure for determining the LID runoff CN.

5.4.2 Maintaining the Pre-development Time of Concentration (Tc)

The LID hydrologic evaluation requires that the post-development time of concentration (Tc) be greater than or equal to the pre-development Tc. The travel time (Tt) throughout individual lots or areas should be approximately the same so that the Tc is representative of the drainage. To maintain the Tc, LID uses the following site planning techniques:

- Maintaining pre-development flow path length by dispersing and redirecting flows, generally, through open swales and natural drainage patterns.
- Increasing surface roughness (e.g., preserving woodlands, using vegetated swales).
- Detaining flows (e.g., open swales, check dams, rain gardens).
- Minimizing disturbance (minimizing compaction and changes to existing vegetation).
- Flattening grades in impacted areas.
- Disconnecting and dispersing runoff from impervious areas (e.g., eliminating curb/gutter and redirecting downspouts).
- Connecting pervious and vegetated areas (e.g., reforestation, tree planting).

To maintain the pre-development Tc, an iterative process that analyzes different combinations of the above appropriate techniques may be required. These site planning techniques are incorporated into the hydrologic analysis computations for post-development Tc to demonstrate an increase in post-development Tc above conventional techniques and a corresponding reduction in peak discharge rates. Figure 5.6 illustrates the hydrologic response to maintaining equal pre-development and post-development Tc.

- For hydrograph 1, refer to Figure 5.2.
- For hydrograph 5, refer to Figure 5.5.
- Hydrograph 6 represents the effects of the LID techniques to maintain the Tc. This effectively shifts the post-peak runoff time to that of the pre-development condition and lowers the peak runoff rate.

The greatest gains for increasing the Tc in a small watershed can be accomplished by increasing the Manning's roughness "n" for the initial surface flow at the top of the watershed and increasing the flow path length for the most hydraulically distant point in the drainage area. After the transition to shallow concentrated flow, additional gains in Tc can be accomplished by:

- Decreasing the slope;
- Increasing the flow length; and
- Directing flow over pervious areas.

In LID sites, the amount of flow in closed channels (pipes) should be minimized to the greatest extent possible. Swales and open channels should be designed with the following features:

- Increase surface roughness to retard velocity.
- Use a network of wider and flatter swales and channels to avoid fast-moving flow (maximum 5cfs for swales during a 10-year, 24-hour storm event).

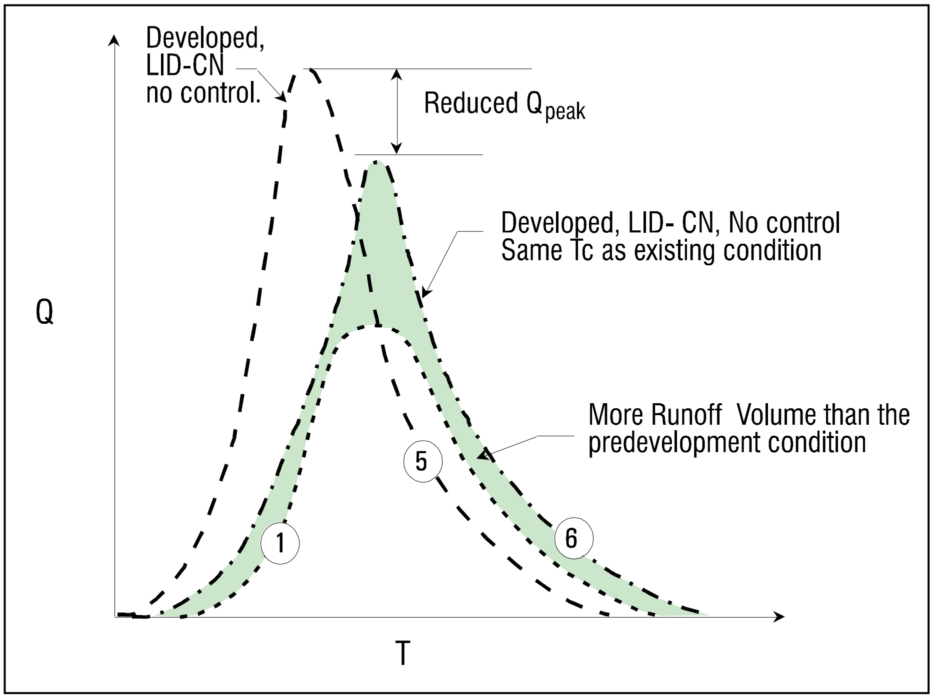


Figure 5.6. LID Hydrograph that has a Reduced CN and Maintains Tc Without BMPs

- Increase channel flow path.
- Maximize swale and channel width to increase storage capacity.
- Reduce channel gradients to decrease velocity .
- The swale and channel should flow over pervious soils wherever possible to increase infiltration and reduce runoff to maximize infiltration capacity.

Table 5.4 identifies LID techniques and volume objectives to maintain pre-development Tc.

Table 5.4. LID Techniques to Maintain the Pre-development Time of Concentration

	Low Impact Development Technique									
LID Objective	On-lot bioretention	Wider and flatter swales	Maintain sheet flow	Clusters of trees and shrubs in flow path	Provide tree conservation/transition zones	Minimize storm drain pipes	Disconnect impervious areas	Save trees & Understory	Preserve existing topography	LID drainage and infiltration zones
Minimize disturbance	☐		☐	☐	☐	☐	☐	☐	☐	
Flatten grades		☐	☐			☐			☐	☐
Reduce height of slopes						☐			☐	☐
Increase flow path (divert and redirect)		☐	☐	☐		☐	☐	☐		
Increase roughness “n”	☐		☐	☐	☐	☐	☐	☐		☐

5.4.3 Maintaining the Pre-development Curve Number and Runoff Volume

Once the post-development Tc is maintained at the pre-development conditions and the impact of CN is minimized, any additional reductions in runoff volume must be accomplished through distributed on-site storm water management techniques. The goal is to select the appropriate combination of management techniques (see Section 6) that emulate the hydrologic functions of the pre-development condition to mimic the existing CN and runoff volume. LID uses retention to accomplish this goal. Placing these facilities strategically located in common areas or on individual lots will provide volume controls at the source.

Retention storage allows for a reduction in the post-development volume and the peak runoff rate. The increased storage and infiltration capacity of retention BMPs allows the pre-development volume to be maintained. Retention BMPs to maintain the pre-development CN include, but are not limited to the following:

- Infiltration trenches;
- Retention ponds;
- Rain barrels;
- Bioretention (Rain Garden);
- Irrigation ponds; and
- Rooftop storage.

As the retention storage volume of the LID BMPs is increased, there is a corresponding decrease in the peak runoff rate in addition to runoff volume reduction. If a sufficient amount of runoff is stored, the peak runoff rate may be reduced to a level at or below the pre-development runoff rate. This concept is illustrated in Figure 5.7. This storage may be all that is necessary to control the peak runoff rate when there is a small change in CN. However, when there is a large change in CN, it may be less practical to achieve flow control using volume control only.

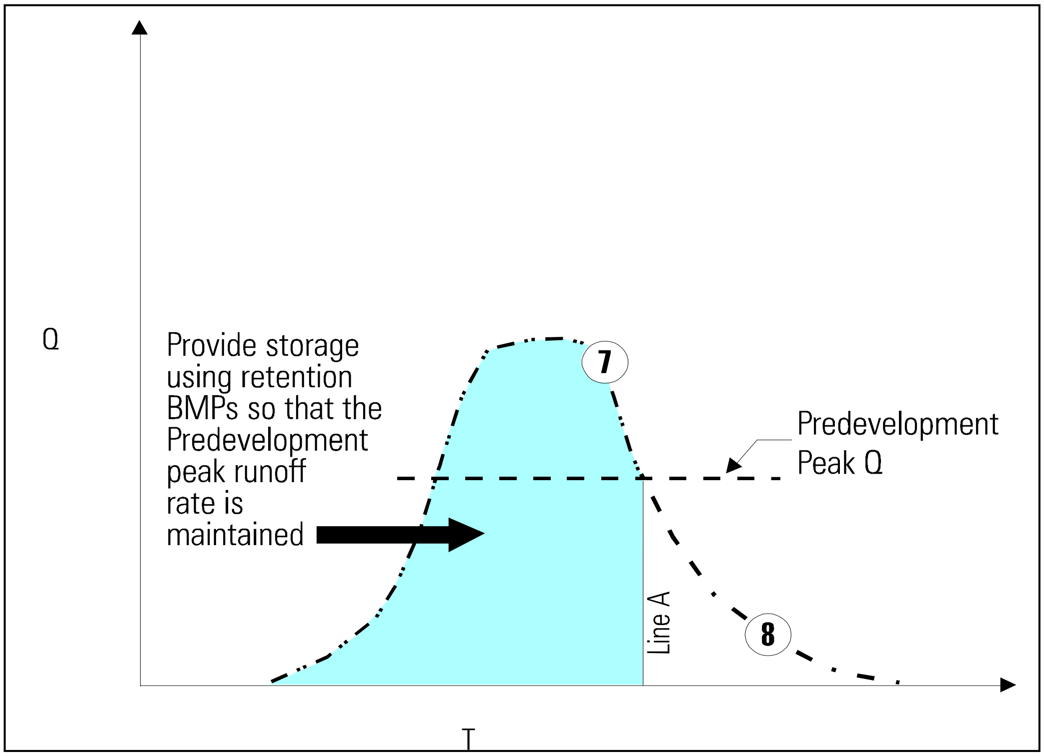


Figure 5.7. Retention Storage Required to Maintain Peak Development Runoff Rate

- Hydrograph 7 represents the BMP inflow hydrograph for the post-development condition for a site using LID. Because of BMP retention storage, runoff is not released until the maximum retention storage volume is exceeded. Line A represents the limit of retention storage.
- Hydrograph 8 is the outflow hydrograph from the LID retention BMP. The release begins at the limit of retention storage, represented by line A. The storage maintains the pre-development volume and controls the peak runoff rate. For this situation, the falling limb of the hydrograph represents a condition where the inflow (hydrograph 7) equals the outflow (hydrograph 8).

5.4.4 Potential Requirement for Additional Detention Storage

Even though the post-development Tc and CN are maintained at the pre-development level, in some cases additional detention storage is needed to maintain the pre-development peak runoff rate due to the spatial distribution of the retention storage provided. The amount of storage that maintains the pre-development runoff volume might not be sufficient to also maintain the pre-development peak runoff rate. Therefore, additional common areas or on-lot storage is required in detention storage. LID storm water management techniques for providing detention storage include, but are not limited to the following:

- Swales with check dams, restricted drainage pipe, and inlet entrances;
- Wider swales;
- Rain barrels;
- Rooftop storage; and
- Diversion structures.

The effect of this additional detention storage is illustrated in Figure 5.8.

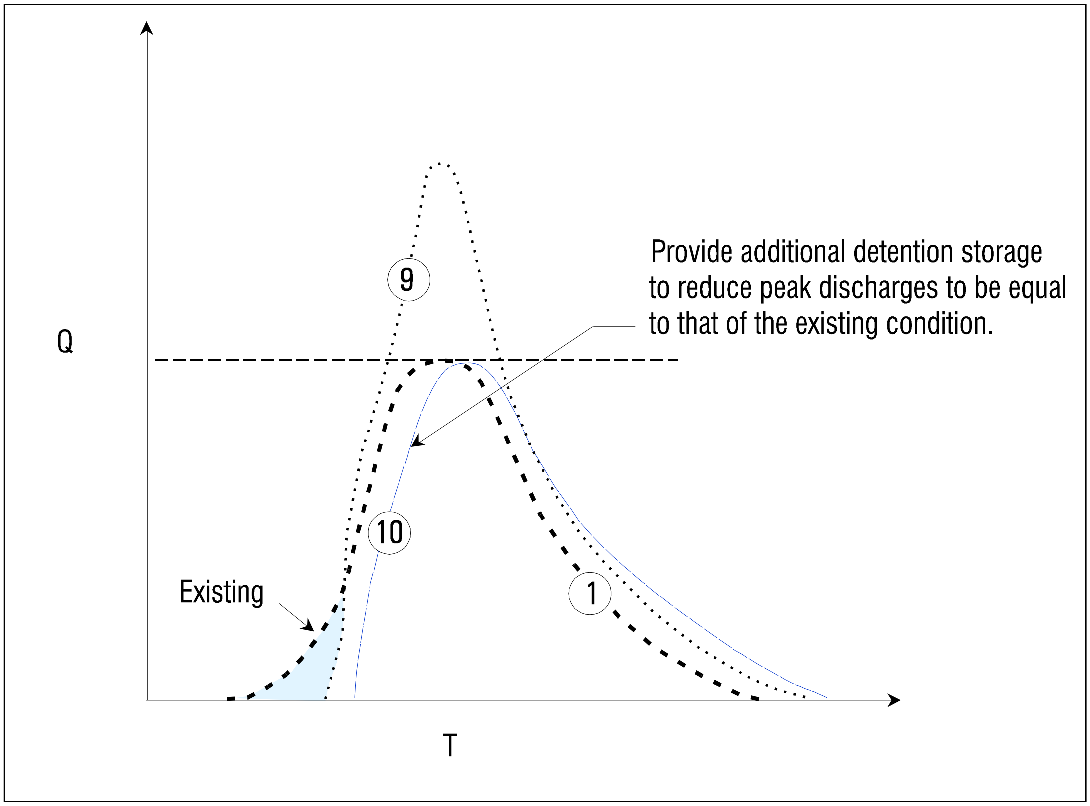


Figure 5.8. Effect of Additional Detention Storage on LID Retention Practices

- For hydrograph 1, refer to Figure 5.2.
- Hydrograph 9 represents the response of a post-development condition that incorporates LID retention practices. The amount of retention storage provided is not large enough to maintain the pre-development peak runoff discharge rate. Additional detention storage is required.
- Hydrograph 10 illustrates the effect of providing additional detention storage (hybrid design, see page 43) to reduce the post-development peak discharge rate to pre-development conditions.

5.5 Process and Computational Procedure for LID Hydrologic Analysis

5.5.1 Introduction

The hydrologic analysis of LID is a sequential decision making process that can be illustrated by the flow chart shown in Figure 5.1. Several iterations may occur within each step until the appropriate approach to reduce storm water impacts is determined. The procedures for each step are given in the following Section. Design charts have been developed to determine the amount of storage required to maintain the existing volume and peak runoff rates to satisfy storm water management requirements (see Appendices B, C, and D).

5.5.2 Data Collection

The basic information used to develop the LID site plan and used to determine the CN and Tc for the pre- and post-development condition is the same as conventional site plan and storm water management approaches.

5.5.3 Determining the LID Runoff Curve Number (CN)

The determination of the LID CN requires a detailed evaluation of each land cover within the development site. This will allow the designer to take full advantage of the storage and infiltration characteristics of LID site planning to maintain the CN. This approach encourages the conservation of more woodlands and the reduction of impervious area to minimize the need of BMPs. The steps for determining the LID CN are as follows:

Step 1: Determine percentage of each land use/cover.
Because LID design emphasizes minimal site disturbance (tree preservation and site fingerprinting), it is possible to retain much of the pre-development land cover and CN. Therefore, it is appropriate to analyze the site as discrete units to determine the CN. Table 5.5 lists representative land cover CNs used to calculate the composite "custom" LID CN.

Table 5.5. Representative LID Curve Numbers

Land Use/Cover	Curve Number for Hydrologic Soils Groups[1]			
	A	B	C	D
Impervious Area	98	98	98	98
Grass (good condition, >75%)	39	61	74	80
Woods (fair condition)	36	60	73	79

[1] Table 2.2, TR-55 (Soil Conservation Service, 1986).

Step 2: Calculate composite custom CN.
The initial composite CN is calculated using a weighted approach based on individual land covers *without* considering disconnectivity of the site imperviousness. This is done using Equation 5.1. This weighted approach is illustrated in Example 5.1.

Equation 5.1.

$$CN_c = \frac{CN_1A_1 + CN_2A_2 ... + CN_jA_j}{A_1 + A_2 ... + A_j}$$

Where:
CNc = composite curve number;
A_j = area of each land cover; and
CN_j = curve number for each land cover

Overlays of Soil Conservation Service (HSG) boundaries onto homogeneous land cover areas are used to develop the LID CN. What is unique about the LID custom made CN technique is the way this overlaid information is analyzed as small discrete units that represent the hydrologic condition, rather than a conventional TR-55 approach that is based on a representative national average. This is appropriate because of the emphasis on minimal disturbance and retaining site areas that have potential for high storage and infiltration. This approach provides an incentive to save more trees and maximize the use of more permeable soils for recharge. Careful planning can result in significant reductions in post-development runoff volume and BMP costs.

Step 3: Calculate LID CN based on the connectivity of site impervious area. When the impervious areas are less than 30 percent of the site, the percentage of the unconnected impervious areas within the watershed influences the calculation of the CN (Figure 2-4, Soil Conservation Service, 1986). Disconnected impervious areas are impervious areas that do not connect to a drainage feature or impervious surface through direct or shallow concentrated flow. For example, roof drains from houses could be directed onto lawn areas where sheet flow occurs, instead of to a swale or driveway where shallow concentrated flow occurs. By increasing the ratio of disconnected impervious areas to pervious areas on the site, the CN and resultant runoff volume can be reduced. Equation 5.2 is used to calculate the CN for sites with less than 30% impervious area.

Equation 5.2.

$$CN_c = CN_p + \left(\frac{P_{imp}}{100}\right) \times (98 - CN_p) \times (1 - 0.5R)$$

where:
R = ratio of unconnected impervious area to total impervious area;
CN_c = composite CN;
CN_p = composite pervious CN; and
P_{imp} = percent of impervious site area

Example 5.1 uses steps 1 through 3 to compare the calculation of the curve number using conventional and LID techniques using the percentages of land cover for a typical 1-acre residential lot from Figure 5.4.

Example 5.1. Detailed CN Calculation

Given:
One-acre residential lot

Conventional CN: 68 (from TR-55 Table 2.2a) Runoff curve numbers for urban areas (Soil Conservation Service, 1986) Table 2.2a assumes HSG B, 20% imperviousness with a CN of 98 and 80% open space in good condition.

Custom Made LID CN: CN for individual land covers based on Table 2.2a. Assume 25% of the site will be used for reforestation/landscaping (see Figure 5.4) HSG B.

Procedure:

Step 1: Determine percentage of each land cover occurring on site and the CN associated with each land cover.

Land Use	**HSG (1)**	**CN (2)**	**% of Site (3)**	**Land Coverage (ft^2) (4)**
Impervious (Directly Connected)	B	98	5	2,178
Impervious (Unconnected)	B	98	10	4,356
Open Space (Good Condition, Graded)	B	61	60	26,136
Woods (Fair Condition)	B	55	25	10,890

Step 2: Calculate composite custom CN (using Equation 5.1).

$$CN_c = \frac{98\times4{,}356+98\times2{,}178+61\times26{,}136+55\times10{,}890}{43{,}560}$$

$$CN_c = 65$$

Step 3: Calculate LID CN based on the connectivity of the site imperviousness (using Equation 5.2).

$$CN_p = \frac{61\times26{,}136+55\times10{,}890}{37{,}026}$$

$$CN_p = 59.2$$

$$R = \frac{10}{15}$$

$$R = 0.67$$

$$CN_c = CN_p + \left(\frac{P_{imp}}{100}\right)\times(98 - CN_p)\times(1-0.5\times R)$$

$$CN_c = 59.2 + \left(\frac{15}{100}\right)\times(98-59.2)\times(1-0.5\times0.67)$$

$$CN_c = 63.1\ (\text{use } 63)$$

LID custom CN of 63 is less than conventional CN of 68 (pre-development CN is 55).

5.5.4 Development of the Time of Concentration (Tc)

The pre- and post-development calculation of the Tc for LID is exactly the same as that described in the TR-55 (Soil Conservation Service, 1986) and NEH-4 (Soil Conservation Service, 1985) manuals. Tc can be maintained through techniques discussed in 5.4.2.

5.5.5 LID Storm Water Management Requirements

Once the CN and Tc are determined for the pre- and post-development conditions, the storm water management storage volume requirements can be calculated. The LID objective is to maintain both the pre-development volume, pre-development peak runoff rate, for each storm frequency. The required storage volume is calculated using the design charts in Appendices B, C, and D. The remaining LID hydrologic analysis techniques are based on the premise that the post-development Tc is the same as the pre-development condition. If the post-development Tc does not equal the pre-development Tc, additional LID site design techniques must be implemented to maintain the Tc. Three series of design charts are needed to determine the storage volume required to control the increase in runoff volume and peak runoff rate using retention and detention practices. The required storages shown in the design charts are presented as a depth in hundredths of an inch (over the development site). Recommended design depths for BMPs are provided in Section 6. Equation 5.3 is used to determine the volume required for BMPs. However, a 12-inch depth is the maximum depth for bioretention basins used in LID.

Equation 5.3.

$$Volume\ for\ BMP = \frac{(depth\ from\ chart,\ inches) \times (development\ size,\ acres)}{100}$$

The amount, or depth, of runoff lost by infiltration or by the process of evapotranspiration is not included in the design charts. Reducing surface area requirements through the consideration of these factors can be determined by using Equation 5.4.

Equation 5.4.

$$Volume\ of\ Site\ Area\ for\ BMP = \frac{(initial\ volume\ of\ site\ for\ BMP) \times (100 - x)}{100}$$

where:
x = % of the storage volume infiltrated and/or reduced by evaporation or transpiration. x% should be minimal (less than 10% is considered).

Storm water management is accomplished by selecting the appropriate BMP, or combination of BMPs, to satisfy the calculations for surface area and volume requirements. The design charts to be used to evaluate these requirements are:

- Appendix B: Storage Volume Required to Maintain the Pre-development Runoff Volume Using Retention Storage.
- Appendix C: Storage Volume Required to Maintain the Pre-development Peak Runoff Rate Using 100% Retention.
- Appendix D: Storage Volume Required to Maintain the Pre-development Peak Runoff Rate Using 100% Detention.

These charts are based on the following general conditions:

- The land uses for the development are relatively homogeneous.
- The storm water management measures are to be distributed evenly across the development, to the greatest extent possible.
- The design storm is based on 1-inch increments. Use linear interpolation for determining intermediate values.

The procedure to determine the BMP requirements is outlined in Figure 5.9 and described in the following Sections.

Step 1: Determine storage volume required to maintain pre-development volume or CN using retention storage. The post-development runoff volume generated as a result of the post-development custom made CN is compared to the pre-development runoff volume to determine the storage volume required for volume control. Use Chart Series in Appendix B: Storage Volume Required to Maintain the Pre-development Runoff Volume Using Retention Storage. The procedure for calculating the depth required for maintaining runoff volume is provided in Example 5.2. The practical and reasonable use of the site must be considered. The BMPs must not restrict the use of the site. The storage volume, expressed as hundredths of an inch, is for volume control only; additional storage may be required for water quality control. The procedure to account for the first 1-inch of rainfall, which is the current Performance Criteria, is found in Step 2.

Step 2: Determine storage volume required for Performance Criteria. The runoff volume, expressed as hundredths of an inch, is then compared to the volume required for water quality control. The volume requirement for storm water management quality control is based on the requirement to treat the first 1-inch of rainfall. This volume can be translated to a percent of the site area by assuming a storage depth of 6 inches. The procedure for calculating the site area required for quality control is provided in Example 5.3. The greater number is used as the required storage volume to maintain the CN. From the results of Example 5.3, 0.0011 inches of storage is required for water quality using retention; from Example 5.2, 0.19 inches of storage is required to maintain the runoff volume using retention. Since the storage required to maintain the volume is larger, in this case 0.19 inches over the site should be reserved for retention BMPs using LID measures.

Step 3: Determine storage volume required to maintain peak storm water runoff rate using 100 percent retention. The amount of storage required to maintain the pre-development peak runoff rate is based on the chart in Appendix C. This chart is based on the relationship between storage volume, $\forall_s / \forall_r$, and discharge, Q_o / Q_i, to maintain the pre-development peak runoff rate.

Where:

$\forall_s$ = volume of storage to maintain the predevelopment peak runoff rate using 100% retention;

$\forall_r$ = post development peak runoff volume;

Q_o = peak outflow discharge rate; and

Q_i = peak inflow discharge rate

Step 1

Determine storage volume required to maintain runoff volume or CN. Use Chart Series in Appendix B: Storage Volume Required to Maintain the Pre-development Runoff Volume Using Retention Storage (Example 5.2).

Step 2:

Determine storage volume for water quality volume requirements. Determine storage volume required for quality control BMPs. Use larger of volumes to maintain CN (Step 1, Example 5.2) or water quality volume (Example 5.3).

Step 3:

Determine storage volume required to maintain predevelopment peak runoff rate using 100% retention. Use Chart Series in Appendix C: Storage Volume Required to Maintain the Predevelopment Peak Runoff Rate Using 100% Retention.

Step 4:

Determine whether additional detention storage is required to maintain pre-development peak runoff rate. Compare the results of Steps 1 and 2 to the results of Step 3. If the storage volume in Steps 1 and 2 is determined to be greater than that in Step 3, the storage volume required to maintain the predevelopment CN also controls the peak runoff rate. No additional detention storage is needed. If the storage volume in Step 1 is less than that in Step 3, additional detention storage is required to maintain the peak runoff rate (Example 5.4).

Step 5 (use if additional detention storage is required):

Determine storage volume required to maintain predevelopment peak runoff rate using 100% detention. Use Chart Series in Appendix D: Storage Volume Required to Maintain the Predevelopment Peak Runoff Rate Using 100% Detention. This is used in conjunction with the Chart Series in Appendices B and C to determine the hybrid volume in Step 6.

Step 6 (use if additional detention storage is required):

Hybrid approach. Use results from Chart Series in Appendices B, C and D to determine storage volume to maintain both the predevelopment peak runoff rate and runoff volume. Refer to Equations 5.5 and 5.6 as found in Example 5.4.

Step 7 (use if additional detention storage is required):

Determine appropriate storage volume available for retention practices. If the storage volume available for retention practices is less than the storage determined in Step 3, recalculate the amount of BMP area required to maintain the peak runoff rate while attenuating some volume using the procedure in Example 5.6 using Equations 5.7 and 5.8.

Figure 5.9. Procedure to Determine Storage Volume Required for BMPs to Maintain Pre-Development Volume and Peak Flow Rate.

Example 5.2: Determine Site Area Required to Maintain Volume (CN) Using Chart Series in Appendix B: Storage Volume Required to Maintain the Pre-development Runoff Volume Using Retention Storage

Given:

Site Area is 18 acres

Existing CN is 60

Proposed CN is 65

Design storm is 3.12 inches (2-year, 24-Hour Event)

Design depth of BMP is 6 inches

Solution: Use Chart Series in Appendix B: Storage Volume Required to Maintain Runoff Volume or CN.

0.19" of storage over the site is required to maintain the runoff volume.

Therefore: 0.57 acres (18 acres x 0.19 / 6) of BMPs distributed evenly throughout the site are required to maintain the runoff volume, or CN.

Additional Considerations:

Account for depths other than 6 inches (using Equation 5.3):

Site BMP Area = 0.57 acres if 6" depth is used

Depth of BMPs = 4"

Size of BMP Area = 0.57 x 6"/4"

Size of BMP Area = 0.855 acres

Account for infiltration and/or evapotranspiration (using Equation 5.4)

If 10% of the storage volume is infiltrated and/or reduced by evaporation and transpiration.

BMP Area = (storage volume) x (100 – x)□/100

BMP Area = 0.57 x (100-10)/100

Area of BMP = 0.51 acres

Example 5.3: Calculation of Volume for Water Quality Control

Given: Water Quality Rainfall = 1.0 inch

Propose CN = 65

Solution:

$$RunoffDepth, Q = \frac{(P - 0.2S)^2}{P + 0.8S} \quad Where P = 1.0 inch, and S = (1000/CN) - 10$$

Q = 0.0011 inches

0.19 inches (from Example 5.2) is more than 0.0011 inches for the Water Quality Control, therefore use the volume of storage for Runoff Volume Control to also meet Water Quality requirement.

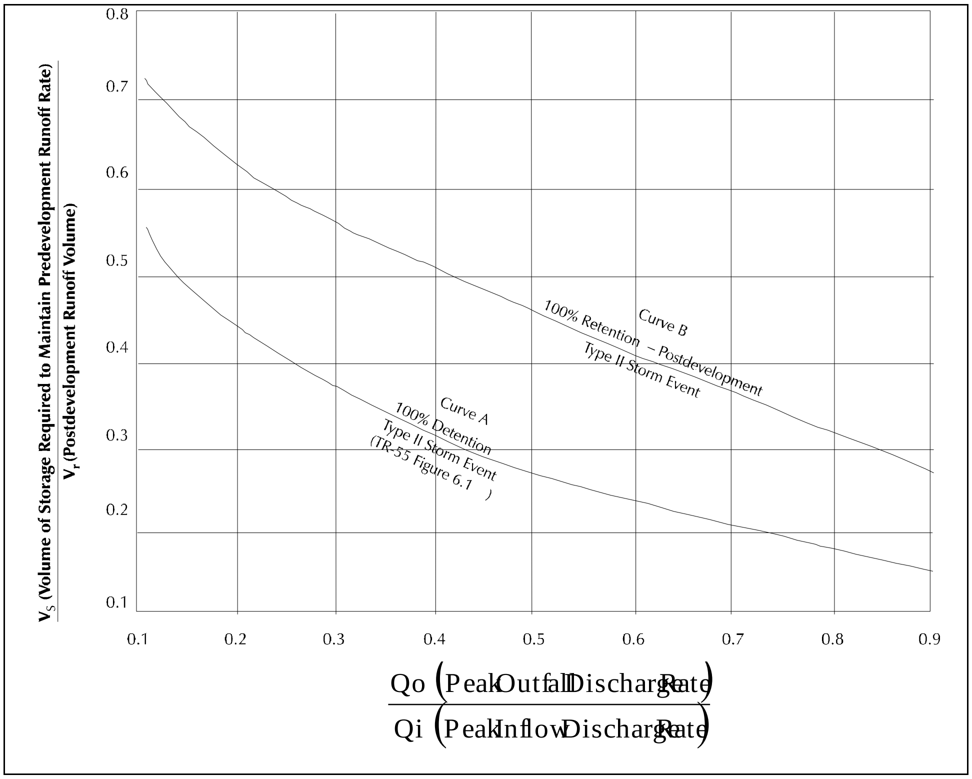


Figure 5.10. Comparison of Retention of Storage Volumes Required to Maintain Peak Runoff Rate Using Retention and Detention

The relationship for retention storage to control the peak runoff rate is similar to the relationship for detention storage. Figure 5.10 is an illustration of the comparison of the storage volume/ discharge relationship for retention and detention. Curve A is the relationship of storage volume to discharge to maintain the pre-development peak runoff rate using the detention relationship from Figure 6.1 of the TR-55 Manual (SCS, 1986) for a Type II 24-hour storm event. Curve B is the ratio of storage volume to discharge to maintain the pre-development peak runoff rate using 100 percent retention. Note that the volume required to maintain the peak runoff rate using detention is less than the requirement for retention. This is graphically demonstrated in Figure 5.11.

- For hydrograph 2, refer to Figure 5.1 for description.
- For hydrograph 10, refer to Figure 5.8 for description.

$\forall_1$ is the storage volume required to maintain the pre-development peak ratio using 100% detention storage. The combination of $\forall_1$ and $\forall_2$ is the storage volume required to maintain the pre-development peak discharge rate using 100% retention storage. The following calculations apply to Chart Series in Appendix C:

- The Tc for the post-development condition is equal to the Tc for the pre-development condition. This equality can be achieved by techniques such as maintaining sheet flow lengths, increasing surface roughness, decreasing the amount and size of storm drain pipes, and decreasing open channel slopes. Section 5.4.2 provides more details on these techniques.
- The depth of storage for the retention structure is 6 inches. For other depths, see Example 5.2.

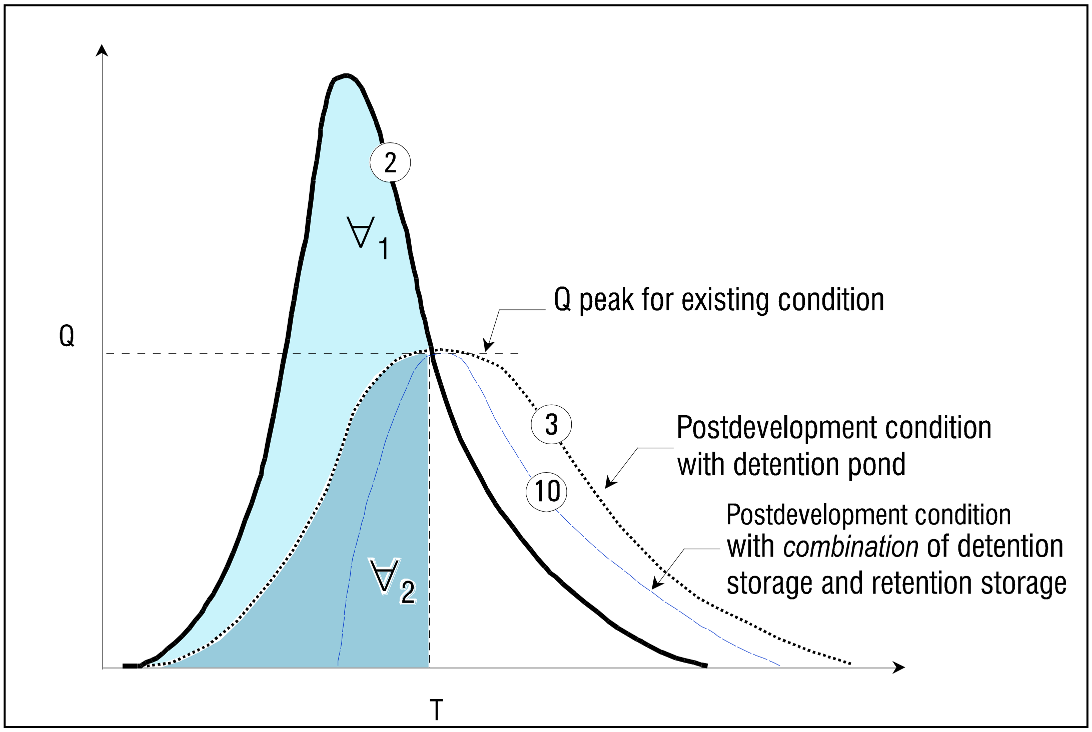


Figure 5.11. Storage Volume Required to Maintain Peak Runoff Rate

If the Tc is equal for the pre-development and post-development conditions, the peak runoff rate is independent of Tc for retention and detention practices. The difference in volume required to maintain the pre-development peak runoff rate is practically the same if the Tc's for the pre-development and post-development conditions are the same. These concepts are illustrated in Figure 5.12. In Figure 5.12 note that the difference in the required BMP area between a Tc of 0.5 and a Tc of 2.0 is minimal if the pre-development and post-development Tc's are maintained.

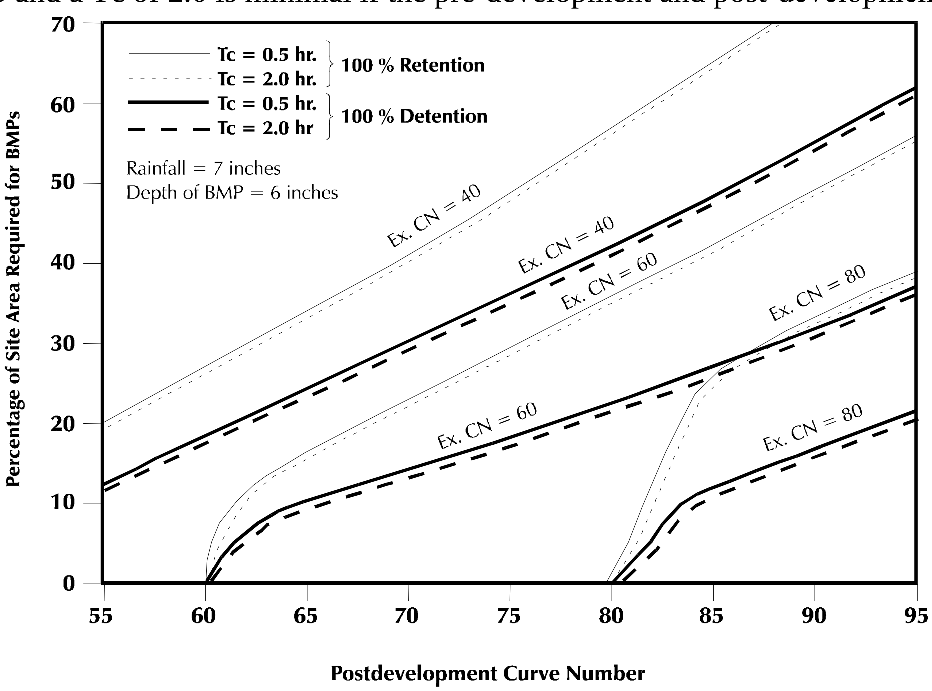


Figure 5.12. Comparison of Storage Volumes for Various Tcs

Step 4: Determine whether additional detention storage is required to maintain the pre-development peak runoff rate. The storage volume required to maintain the pre-development volume using retention, as calculated in Step 1, might or might not be adequate to maintain both the pre-development volume and peak runoff rate. As the CNs diverge, the storage requirement to maintain the volume is much greater than the storage volume required to maintain the peak runoff rate. As the CNs converge, however, the storage required to maintain the peak runoff rate is greater than that required to maintain the volume. Additional detention storage will be required if the storage volume required to maintain the runoff volume (determined in Step 1) is less than the storage volume required to maintain the pre-development peak runoff rate using 100 percent retention (determined in Step 3). The combination of retention and detention practices is defined as a hybrid BMP. The procedure for determining the storage volume required for the hybrid approach is described in Step 5. Table 5.6 illustrates the percentage of site area required for volume and peak control for representative curve numbers. For example, using a 5-inch Type II 24-hour storm event, with a pre-development CN of 60, the following relationships exist:

- For a post-development CN of 65, 5.9 percent of the site area (column 4) is required for retention practices to maintain the pre-development volume. To maintain the pre-development peak runoff rate (column 5), 9.5 percent of the site is required. Therefore, additional detention storage or a hybrid approach (calculated in column 7) is required.
- For a post-development CN of 90, 42.9 percent of the site area (column 4) is required for retention practices to maintain the pre-development volume. To maintain the pre-development peak runoff rate (column 5) 37.2 percent of the site is required. Therefore, the storage required to maintain the runoff volume is also adequate to maintain the peak runoff rate. However, 42.9 percent of the site for BMPs is not a practical and reasonable use of the site. Refer to Step 7, hybrid approach, for a more reasonable combination of retention and detention storage.

Step 5: Determine storage required to maintain pre-development peak runoff rate using 100 percent detention. (This step is required if additional detention storage is needed.) Charts contained in Appendix D: Storage Volume Required to Maintain the Pre-development Peak Runoff Rate Using 100% Detention are used to determine the amount of storage to maintain the peak runoff rate only. This information is needed to determine the amount of detention storage required for hybrid design, or where site limitations prevent the use of retention storage to maintain runoff volume. This includes sites that have severely limited soils for infiltration or retention practices. The procedure to determine the site area is the same as that of Step 3. Using chart contained in Appendix D, the following assumptions apply:

- The Tc for the post-development condition is equal to the Tc for the pre-development condition.
- The depth of storage for the detention structure is 6 inches. For other depths, see Example 5.2.
- The storage volume, expressed as a depth in hundredths of an inch, is for peak flow control.

These charts are based on the relationship and calculations from Figure 5.1 (Approximate Detention Basin Routing for Rainfall Types I, IA, II and III) in TR-55 (SCS, 1986).

Table 5.6. Representative Percentages of Site Required for Volume and Peak Control

Type of 24-Hour Storm Event (1)	Runoff Curve No. Existing (2)	Runoff Curve No. Proposed (3)	% of Area Needed for BMP: Volume Control Using 100% Retention Appendix B (4)	% of Area Needed for BMP: Peak Control Using 100% Retention Appendix C (5)	% of Area Needed for BMP: Peak Control Using 100% Detention Appendix D (6)	Hybrid Design (Eq. 5.6) (7)	Percent of Volume Retention for Hybrid Design (Eq. 5.5) (8)
3”	**50**	55	1.7	1.6	0.9	1.7	100
		60	4.0	3.4	2.4	4.0	100
		65	6.9	6.2	4.5	6.9	100
		70	10.4	9.3	7.3	10.4	100
		80	19.3	18.0	15.8	19.3	100
	60	65	2.9	3.9	2.3	3.6	80
		70	6.3	6.7	4.4	6.6	96
		75	10.5	10.0	7.1	10.5	100
		90	27.5	24.9	18.7	27.5	100
	70	75	4.1	5.9	3.4	5.3	77
		80	8.9	9.7	5.8	9.5	94
		85	14.6	13.9	8.8	14.6	100
		90	21.2	18.7	12.6	21.2	100
	75	80	4.8	7.5	4.2	6.6	73
		85	10.5	11.8	7.0	11.4	91
		90	17.1	16.6	10.2	17.1	100
5”	**50**	55	4.8	6.9	4.0	6.3	77
		60	10.1	11.1	6.9	10.9	93
		65	16.0	15.6	10.4	16.0	100
		70	22.4	20.6	14.5	22.4	100
		80	36.7	32.8	23.9	36.7	100
	60	65	5.9	9.5	5.3	8.3	71
		70	12.3	14.6	8.4	13.9	88
		75	19.1	19.8	12.0	19.6	97
		90	42.9	37.2	25.3	42.9	100
	70	75	6.9	13.2	7.2	10.9	63
		80	14.3	18.9	10.7	17.4	82
		85	22.2	24.5	14.3	23.8	93
		90	30.7	30.5	18.2	30.7	100
	75	80	7.4	15.0	8.1	12.3	60
		85	15.3	20.6	11.6	18.9	81
		90	23.8	26.7	15.2	25.7	92
7”	**50**	55	7.6	12.3	6.8	10.7	71
		60	15.6	18.6	10.7	17.7	88
		65	23.9	25.0	15.1	24.7	97
		70	32.5	31.4	19.6	32.5	100
		80	50.5	44.5	30.0	50.5	100
	60	65	8.3	16.6	9.0	13.6	61
		70	16.9	23.2	13.2	21.2	80
		75	25.8	29.9	17.3	28.7	90
		90	53.7	49.7	30.7	53.7	100
	70	75	8.9	20.4	10.9	16.1	55
		80	17.9	26.8	14.7	23.8	75
		85	27.2	33.4	18.9	31.5	87
		90	36.7	42.3	23.0	39.2	94
	75	80	9.1	22.1	11.5	17.1	53
		85	18.4	28.6	15.6	25.1	73
		90	27.9	35.3	19.8	32.9	85

Step 6: Use hybrid facility design (required for additional detention storage).

When the storage volume for peak control exceeds that for volume control as determined in Step 3, a hybrid approach must be used. For example, a dry swale (infiltration and retention) may incorporate additional detention storage. Equation 5.5 is used to determine the ratio of retention to total storage. Equation 5.6 is then used to determine the additional storage volume, above the storage volume required for runoff volume control, needed to maintain the pre-development peak runoff rate.

Equation 5.5.

$$x = \frac{50}{(\forall_{R100} - \forall_{D100})} \times \left(-\forall_{D100} + \sqrt{\forall^2_{D100} + 4 \times (\forall_{R100} - \forall_{D100}) \times \forall R}\right)$$

where

□ $\forall R$ = Storage volume required to maintain pre-development runoff volume (see Chart Series in Appendix B)

□ $\forall_{R100}$ = Storage volume required to maintain pre-development peak runoff rate using 100% retention (see Chart Series in Appendix C)

$\forall_{D100}$ = Storage volume required to maintain pre-development peak runoff rate using 100% detention (see Chart Series in Appendix D)

x = Area ratio of retention storage to total storage

Equation 5.6.

H = □ $\forall R$ x (100 ÷ x)

where:

H = Hybrid storage volume

Equations 5.5 and 5.6 are based on the following assumptions:

- x% of the total storage volume is the retention storage required to maintain the pre-development CN calculated from the Chart Series in Appendix B: Storage Volume Required to Maintain Pre-development Volume using Retention Storage.
- There is a linear relationship between the volume of storage required to maintain the peak pre-development runoff rate using 100% retention and 100% detention (Chart Series in Appendices C and D) .

The procedure for calculating hybrid facilities size is shown in Example 5.4.

Example 5.4: Calculation of Additional Storage Above Volume Required to Maintain CN and Maintain Pre-development Peak Runoff Rate Using Hybrid Approach

Given:

- 3.12 -inch Storm Event (2-year, 24-hour event)
- Existing CN = 60
- Proposed CN = 65
- Storage volume required to maintain volume (CN) using retention storage = 0.19 inches (from Chart Series in Appendix B)
- Storage volume required to maintain peak runoff rate using 100% retention = 0.275 inches (from Chart Series in Appendix C)

- Storage of site required to maintain peak runoff rate using 100% detention = 0.14 inches (from Chart Series in Appendix D)

Step 1: Solve for x (ratio of retention to total storage) using Equation 5.5:

$$x = \frac{50}{(0.275 - 0.14)} \times \left(-0.14 + \sqrt{0.14^2 + 4(0.275 - 0.14) \times 0.19}\right)$$

x = 77.62

Therefore: 0.19 inches of storage needed for runoff volume control is 77.62% of the total volume needed to maintain both the pre-development volume & peak runoff rates.

Step 2: Solve for the volume to maintain both the peak runoff rate and volume using Equation 5.6.

H = 0.19 x 100 / 67

H= 0.24 inches

Therefore, the difference between 0.19 inches and 0.24 inches is the additional volume needed to maintain peak discharge using 100% retention.

Step 7: Determine hybrid amount of BMP site area required to maintain peak runoff rate with partial volume attenuation using hybrid design (required when retention area is limited).

Site conditions, such as high percentage of site needed for retention storage, poor soil infiltration rates, or physical constraints, can limit the area of the site that can be used for retention practices. For poor soil infiltration rates, bioretention is still an acceptable alternative, but an underdrain must be installed. In this case, the bioretention basin is considered detention storage. When this occurs, the amount available for retention BMPs is less than that required to maintain the volume, or CN. A variation of the hybrid approach is used to maintain the peak runoff rate while attenuating as much of the increased runoff volume as possible. First, the appropriate storage volume available for volume control $(\forall R)$ is determined by analyzing the site constraints. Equation 5.7 is used to determine the ratio of retention to total storage. Equation 5.8 is then used to determine the total site BMP area in which the storage volume available for retention practices (∀R') is substituted for the storage volume required to maintain the runoff volume.

Equation 5.7

$$X' = \frac{50}{(\forall_{R100} - \forall_{D100})} \times \left(-\forall_{D100} + \sqrt{\forall^2_{D100} + 4 \times (\forall_{R100} - \forall_{D100}) \times \forall R'}\right)$$

where:

∀R = storage volume acceptable for retention BMPs. The total storage with limited retention storage is:

Equation 5.8

$H' = \forall R' \times (100 \div X')$

H'= Hybrid area, with a limited storage volume available for retention BMPs.

Example 5.5 illustrates this approach.

Example 5.5: Calculation of Storage Volume Required to Maintain the Peak Runoff Rate Using the Hybrid Approach of Retention and Detention

Given:

- 3.12-inch storm event (2-year, 24-hour event)
- Existing CN = 60
- Proposed CN = 65
- Storage volume required to maintain volume (CN) = 0.19” (from Appendix B)
- Storage volume required to maintain peak runoff rate using 100% retention = 0.275” (from Appendix C)
- Storage volume required to maintain peak runoff rate using 100% detention = 0.14” (from Appendix D)
- Only half of the required site area is suitable for retention practices, remainder must incorporate detention.
- (R’=0.19 x 0.50 = 0.095)

Step 1: Determine appropriate amount of overall BMP volume suitable for retention practices. Half of area is appropriate (given above). Use Equation 5.7:

$$x' = \frac{50}{(.275 - .14)} \times \left(-.14 + \sqrt{.14^2 + 4 \times (.275 - .14) \times 0.095} \right)$$

$$x' = 46.77\%$$

Therefore, 0.095 inches of storage available for runoff volume control on the site is 46.77% of total volume needed for maintaining the pre-development peak runoff rate.

Step 2: Solve for the total storage required to maintain the peak runoff rate using Equation 5.8. Solve for H’

$$H' = 0.095\left(\frac{100}{46.77}\right)$$

$$H' = 0.20\ inches$$

Therefore, 0.20” of storage is required to maintain predevelopment peak runoff rate but not runoff volume. Of the 0.20” of storage, 0.095” is required for retention volume.

5.5.6 Determination of Design Storm Event

Conventional storm water management runoff quantity control is generally based on not exceeding the pre-development peak runoff rate for the 2-year and 10-year 24-hour Type II storm events. The amount of rainfall used to determine the runoff for the site is derived from Technical Paper 40 (Department of Commerce, 1963). For Mecklenburg County, these rainfall amounts are 3.12 and 4.80 inches, respectively. The 2-year storm event was selected to protect receiving channels from sedimentation and erosion. The 10-year event was selected for adequate flow conveyance considerations. In situations where there is potential for flooding of structures, the 100-year event is used. For LID the design storm event shall be the 2-year, 24-hour storm. Post-developed peak and volume shall not exceed the pre-developed peak and volume.

Section 6. LID Site Design Best Management Practices (BMPs)

6.1 Introduction

In Section 5, the required runoff storage volume, expressed in hundredths of an inch, and the type of best management practice (BMP) required for its control (i.e., retention, detention, or hybrid) were determined through a systematic hydrologically-based process. Section 5 explored site planning considerations for maintaining the curve number (CN) and time of concentration (Tc), which can be used to achieve the objectives of Section 5. This Section builds upon the planning strategies presented in Sections 4 and 5 by providing considerations key to the proper design of the BMPs. The Section begins with a definition and description of the functions provided by various types of LID BMPs that are available to the designer and concludes by outlining some consideration for their design.

6.2 LID BMPs and Their Functions

LID BMPs are sited and designed to provide the following:
- Site hydrologic source controls for Tc, CN, and ground water recharge.
- Small common area or on-lot BMPs that are more easily maintained.
- An added aesthetic value.
- Multiple use of landscaped areas. In some cases, the on-lot or commercial hydrologic control also can satisfy the Town of Huntersville's requirements for green or vegetated buffer space.

LID site design techniques and BMPs can be organized into four major categories, as follows:
- Pollution prevention practices that contribute to the overall improvement of water quality.
- Runoff prevention measures designed to minimize impacts that would otherwise change the pre-development curve number (CN) and time of concentration (Tc).
- Retention facilities that store runoff and have no positive outlet, or release, for the design storm event. Excess runoff is infiltrated, exfiltrated, or evaporated.
- Detention facilities that temporarily store a portion of the increased runoff volume and release it through a measured outlet.

LID BMPs shall be applied in the following order of preference:
<u>Step One:</u> Incorporate runoff reduction BMPs into the design to minimize changes in the site hydrology, which result from changes in the CN and Tc.
<u>Step Two:</u> Meet site storm water quality treatment objectives through the use of retention/detention practices.
<u>Step Three:</u> Use retention BMPs, to the greatest extent possible, for storm water management volume and peak flow rate control, using the procedures from Section 5.
<u>Step Four:</u> Use detention and hybrid BMPs if required.
<u>Step Five:</u> Use pollution prevention through source reduction and elimination.

Tables 6.1 and 6.2 provide a list of BMPs approved for use to satisfy the Huntersville Post-Construction Ordinance as well as the applicable zones for use of the BMPs in Huntersville (Urban, Transitional, Rural), the section of the Performance Criteria (see Section 3) they are best suited to satisfy and whether they serve a water quality or volume control function (WQ or VC).

These lists are not all inclusive. New BMPs will be reviewed and adapted on a case-by-case basis by the Mecklenburg County Water Quality Program as they are made available. In addition, BMPs placed in series in the form of a treatment train or modifications to BMP designs can be developed to combine both retention and detention storage. Placing BMPs in treatment trains will provide for the maximum on-lot storm water runoff control (i.e., maximum mitigation of site development impacts on CN and Tc). This type of design BMP is known as a "hybrid." Hybrid BMPs can be used to increase the post-development Tc. Table 6.1 gives each LID BMP type and its primary function. The design source for all the BMPs in Tables 6.1 and 6.2 is the Charlotte-Mecklenburg BMP Design Manual developed by Charlotte-Mecklenburg Storm Water Services unless otherwise designated below

Table 6.1. Approved LID BMPs for Use in Huntersville

BMP	Applicable Zoning Districts (1)	Applicable Performance Criteria (2)	Designs & Specifications (3)	Function (4) (WQ, VC, PC)
Bioretention (Rain Garden)	U, T, R	3(a), 3(b)	Chapter 12 NCDENR BMP Design Manual (6)	WQ, VC, PC
Infiltration Trench	U, T, R	3(a), 3(b)	Chapter 4.6	WQ, VC, PC
Enhanced Grass Swale	U, T, R	3(a)	Chapter 4.4	WQ, VC
Grass Channel	U, T, R	3(a)	Chapter 4.5	WQ
Filter Strip/Wooded Buffer Strip	U, T, R	3(a)	Chapter 4.7	WQ, PC
Dry Well, Cistern & Rain barrel	U, T, R	3(b)	Chapter 19 NCDENR BMP Manual (6)	WQ, VC, PC
Curb & Gutter Elimination	R	3(b)		WQ, PC
Rooftop Storage	U, T, R	3(b)	Chapter 19 NCDENR BMP Manual (6)	VC, PC
Sand Filter (5)	U, T, R	3(a), 3(b)	Chapter 4.8	WQ, VC, PC

(1) Applicable Zoning Districts: These are the Zoning Districts where the BMP can be used including: T = Transitional; R = Rural; and U = All other zones EXCEPT transitional and rural.

(2) Applicable Performance Criteria: These are the Performance Criteria Section numbers (see Section 3) that the BMP can be used to satisfy.

(3) Designs & Specifications: All BMP designs and specifications are contained in the Charlotte-Mecklenburg BMP Design Manual in the specific chapter indicated in the above table unless noted.

(4) Functions: These are the dominate functions that the BMPs perform including: WQ = Water Quality; VC = Volume Control, PC = Peak Control.

(5) Sand Filter: To be considered an LID BMP, the sand filter must be above ground with a native soil bottom that has been scarified and not compacted. A double-ringed infiltrometer test of the bottom must show infiltration capabilities. In addition, the under drain must be designed to create minimum two-foot internal water storage layer above the bottom. Sand filters not meeting these criteria will be considered Conventional Storm Water BMPs.

(6) Design & Specifications contained in Chapter 19 of the NCDENR Storm Water BMP Design Manual and NCDENR's Technical Guidance for Rainwater Harvesting Systems located at: http://portal.ncdenr.org/web/wq/ws/su/bmp-ch19

Table 6.2. Approved Conventional BMPs for Use in Huntersville

BMP	Applicable Zoning Districts (1)	Applicable Performance Criteria (2)	Designs & Specifications (3)	Function (4) (WQ, VC, PC)
Wet Pond	U, T, R	3(b), 3(d)	Chapter 4.2	WQ, VC, PC
Extended Dry Pond	T, R	3(b), 3(d)	Chapter 4.9	VC, PC
Storm Water Wetland	T, R	3(b)	Chapter 4.3	WQ, VC, PC

(1) Applicable Zoning Districts: These are the Zoning Districts where the BMP can be used including: T = Transitional; R = Rural; and U = All other zones EXCEPT transitional and rural.
(2) Applicable Performance Criteria: These are the Performance Criteria Section numbers (see Section 3) that the BMP can be used to satisfy.
(3) Designs & Specifications: All BMP designs and specifications are contained in the Charlotte-Mecklenburg BMP Design Manual in the specific chapter indicated in the above table unless otherwise noted.
(4) Functions: These are the dominate functions that the BMPs perform including WQ = Water Quality; VC = Volume Control, PC = Peak Control.

The functions listed in Table 6.1 are subdivided into two major categories as follows:

- Water Quality: All water quality BMPs shall be designed to achieve an average annual 85% Total Suspended Solids (TSS) removal for the developed area of the site. The BMPs shall treat runoff generated from the first inch of rainfall. LID BMPs or a combination of LID and Conventional BMPs as described in Tables 6.1 and 6.2 shall be used to meet these water quality Performance Criteria. If a combination of LID and Conventional BMPs is used, then at a minimum the first 50% of the runoff from the one (1) inch storm event must be treated using LID BMPs. The remaining 50% shall be treated using Conventional BMPs capable of achieving the above described pollutant removal efficiency. No one bioretention BMP shall exceed 5,000 square feet of soil media surface area.
- Volume Control: LID BMPs or a combination of LID and Conventional BMPs (see Tables 6.1 and 6.2) shall be used to control and treat the increase in storm water runoff volume associated with post-construction conditions as compared with pre-construction (existing) conditions for the 2-year frequency, 24-hour duration storm event in the Rural and Transitional Zoning Districts. For all other Zoning Districts, LID BMPs or a combination of LID and Conventional BMPs shall be used to control and treat the increase in storm water runoff volume associated with post-construction conditions as compared with pre-construction (existing) conditions for the 1-year frequency, 24-hour duration storm event. Where any storm water BMP employs the use of a temporary water quality storage pool as a part of its treatment system, the drawdown time shall be a minimum of 48 hours and a maximum of 120 hours.
- Peak Control: The peak storm water runoff release rates leaving the site during post-construction conditions shall be equal to or less than the pre-development peak storm water runoff release rates for the 2-year frequency, 24-hour duration storm event and 10-year frequency, 24-hour duration storm event. The emergency overflow and outlet works for any pond or wetland constructed as a storm water BMP shall be capable of safely passing a discharge with a minimum recurrence frequency of 50 years. For detention basins, the temporary storage capacity shall be restored within 72 hours. Requirements of the Dam Safety Act shall be met when applicable.

Some approaches are used to convey storm water while minimizing or eliminating erosion potential. For example, a swale can be designed to detain, retain, and control runoff velocities simply by altering its geometry and slope and adding an infiltration trench beneath the swale and a weir control structure at the inlet of the culvert beneath the driveway (see Figure 6.1). The implication of this is that velocities are reduced and particulate matter is infiltrated or filtered from the runoff prior to its delivery to a particular BMP or downstream receiving water body. Some conveyance techniques also can be designed specifically for runoff water quality treatment if that objective is considered during the concept plan design.

6.2.1 "Helpful Hints" for the Proper Design and Installation of BMPs

The following is a list of "Helpful Hints" that are oftentimes overlooked but which are very important for ensuring the proper design and installation of BMPs:

1. All plans and details for BMPs must be drawn to scale for clarity and to aid in construction. Drawings not to scale often lead to construction problems and field errors, or simply cannot be built. Standard NCDOT details do not require a specific scale.
2. Do not assume the final elevations based on contour maps as their accuracy is only 1/2 the contour interval. Use in-field elevations to set final grades for BMPs and flared end sections.
3. All bioretention plans must contain sufficient contours (1 foot increment) and spot elevations to accurately construct in the field.
4. Make sure you have shown roof leaders that may directly connect to bioretention BMPs. These must discharge as sheet flow into the bioretention areas and not as a point source. Care must be taken to show the end invert of these pipes as they will control the final elevation of the mulch layer.
5. Clearly show all elevations on BMP plans, cross sections and details that impact the design of the BMP. Show all inverts, top of mulch, top of berm, spillway etc. elevations to insure that proper construction can be accomplished.
6. The required surface area for the BMP must be clearly shown on the plan in square feet and graphically depicted for clarity.
7. The biggest threat to the functionality of a bioretention area is sediment, which will clog the soil media and prevent infiltration. Take great care to prevent sediment from entering the bioretention area by surrounding it with silt fence and ensuring that the land draining to the area has been stabilized. Additional information regarding erosion and sediment control is provided in Section 7.
8. It is extremely important to properly dissipate the flow entering a bioretention area through the use of level spreaders as discussed in Section 6.5.

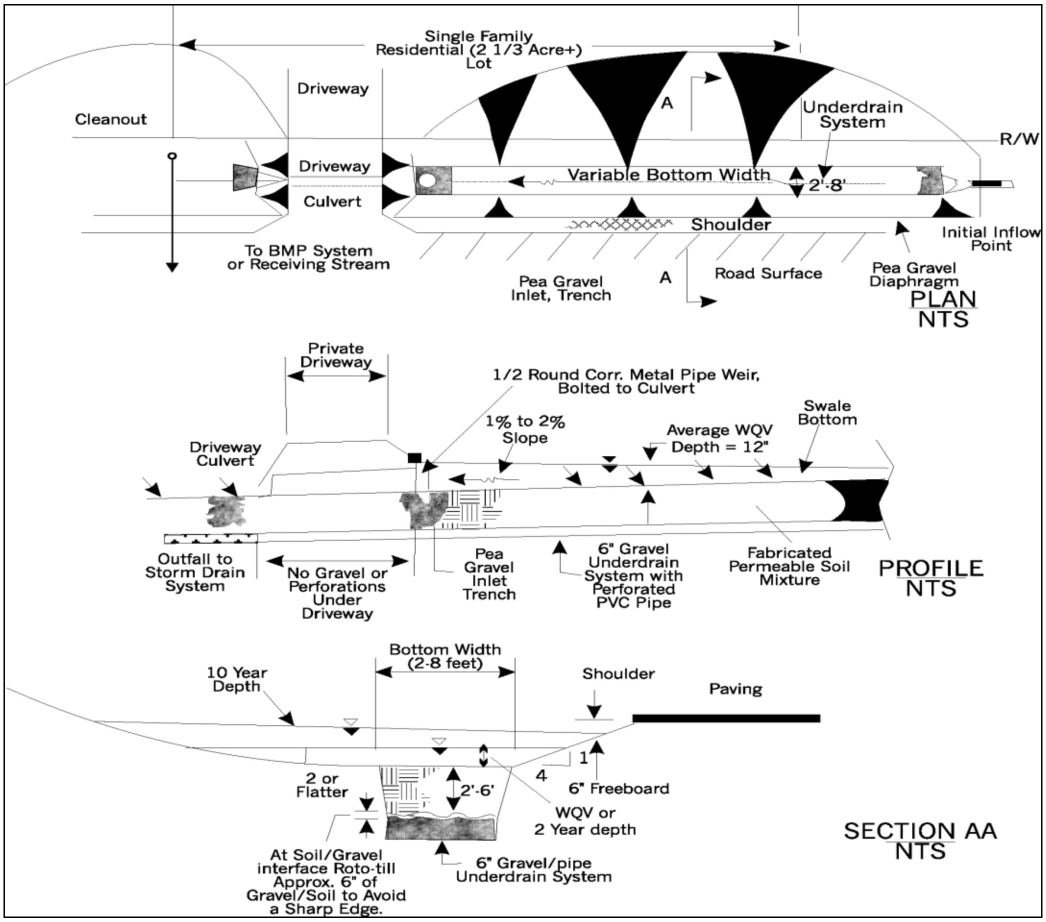


Figure 6.1. Typical Swale Design

6.3 Runoff Reduction BMPs

Runoff reduction BMPs are site development practices that are implemented to reduce changes in storm water runoff volume and peak flow rate. This is accomplished by minimizing changes to pre-development land cover, reducing impervious surfaces, and preserving trees, especially those found on pervious soils. Runoff reduction BMPs are the first line of defense to reduce changes in existing land cover and to disconnect "effective" impervious surfaces. These runoff reduction BMPs may be the least expensive way to minimize CN impacts and maintain existing Tc. By including these techniques, the need for retention and detention BMPs to mitigate development hydrologic impacts is reduced. A brief description of these techniques/practices is provided below.

Strategic clearing and grading practices are the most effective method of reducing storm water quantity and erosion impacts on downstream receiving waters and aquatic habitat. Minimizing clearing and grading within forested and densely vegetated areas is the most efficient method of reducing changes to the CN. This is due to the natural dispersion and infiltration function of forests and densely vegetated areas. It is possible to increase the post-development Tc by flattening the slopes, increasing the flow path, maximizing sheet flow, and increasing surface roughness on cleared areas.

Vegetated buffers are strips of vegetation, either natural or planted, around sensitive areas, such as water bodies, wetlands, or highly erodible soils. In addition to protecting sensitive areas, vegetated strips help to reduce storm water runoff impacts by trapping sediment and sediment-bound pollutants, encouraging infiltration, and slowing and dispersing storm water flows over a wide area.
Proper landscaping is one method of mitigating the hydrologic impacts of clearing and grading. In some cases, a large portion of the site will have to be cleared and graded, resulting in the loss of much woody vegetation and debris. A carefully designed landscaping plan can be used to reestablish some of the vegetative functions lost during this process. Heavily revegetated areas can improve sediment removal, infiltration, and community aesthetics.
Curb elimination or flat curbs addresses both quantity as well as water quality functions. When curbs are removed flattened or depressed, site imperviousness is disconnected by allowing storm water runoff, normally conveyed along the gutter and discharged directly into a storm drain BMP or receiving water body, to be dispersed to vegetated buffer areas or roadside swales. This process helps to minimize CN impacts, increase or maintain the TC, and filter pollutants leaving a given site.

Changes in CN due to clearing and grading and the addition of impervious surfaces result in changes in storm water runoff volume and peak flow rate. Both the pre- and post-development CNs must be determined to evaluate the magnitude of change and potential requirement for retention and detention storage volume. By reducing the change in CN, the requirement for onsite BMP storage area is reduced. Calculation of the post-development CN should be based on prototypical lot layouts that represent the LID design techniques that will be incorporated into the development.

6.4 Retention BMPs

LID BMPs are used to satisfy the water quality and storage volume requirements (Sections 3(a) and 3(b)) calculated in Section 5. They are the preferred method because they maintain the pre-development runoff volume. Therefore, they are the most effective method for managing the hydrologic regime. In the hydrologic analysis presented in Section 5, storage volume for retention is first calculated to maintain pre-development runoff volume and peak flow rate. These BMPs are sized to retain 100% of the excess post-development volume; however, under some circumstances additional detention storage will be required. Ideally, the design goal is to locate retention BMPs at the source on level ground within individual lots of the development. LID retention BMPs include standard infiltration-type facilities. They typically are designed and located to provide retention controls for very small drainage areas serving up to 2 to 5 acres. Retention BMPs that are applicable to LID include multifunctional landscape areas, bioretention facilities, dry wells, and roof runoff controls such as rain barrels and cisterns. The use of runoff reduction BMPs is important. In the case of commercial and industrial zoned properties, the minimum internal landscaping requirements plus the size of perimeter buffers and perimeter parking landscape will dictate the feasibility of providing all required storage within surface swales or bioretention facilities. (Refer to the Town of Huntersville's Zoning Ordinance and landscape manual for specific requirements). The following provides a brief description of retention BMPs.

- Bioretention: Bioretention BMPs (also called Rain Gardens) are applicable as retention facilities for treatment of storm water runoff. Typically they are designed to mimic forested BMPs that naturally control hydrology through infiltration and evapotranspiration. They are especially suited to residential and commercial areas where additional landscaping can provide aesthetic benefits. Figure 6.2 shows a typical plan and detail for a bioretention cell. Design Considerations: In addition to design criteria currently listed in various State and local manuals, the following design considerations should be followed for LID sites. Bioretention areas should include an upstream pretreatment system. The type of pretreatment used depends on the type of land use in the upstream service area. It is recommended that at a minimum bioretention areas incorporate vegetated filter strips as pretreatment devices. In commercial areas where space is limited, parking area sweeping is recommended as a pretreatment practice. It is further recommended that bioretention areas be placed "off-line." The first flush must be diverted to the BMP and those flows in excess of the first inch of rainfall should be bypassed. Experience has shown that bioretention BMPs that receive runoff from all storm events require greater maintenance and have an increased rate of failure. Make sure you have shown roof leaders that directly connect to bioretention areas. These must discharge as sheet flow into the bioretention areas and not as a point source. Care must be taken to show the end invert of these pipes as they will control the final elevation of the mulch layer.

- Dry Wells: Dry wells are small excavated trenches backfilled with stone. Dry wells function as infiltration BMPs used to control runoff from building rooftops. Figure 6.3 shows a typical detail for a dry well.
  Design Considerations: Dry wells should infiltrate the design storm within three (3) days from the beginning of the storm. Dry wells should be located close to runoff sources. However, they must be located a sufficient distance away on the down slope side of the structure and from building foundations to prevent seepage into basements. The designer must make sure to site these facilities away from slopes >20%, particularly when the slope consists of fill materials over native ground. The designer must also ensure that the overflow is directed to the down-slope bioretention BMPs, swales, or other management areas in a non-erosive fashion. Conveyance areas should be well vegetated and have slopes of <5%, or appropriately sized riprap should be used.

- Cisterns: Storm water runoff cisterns are roof water management devices that provide retention storage volume in underground storage tanks. On-lot storage and later reuse of storm water also provides an opportunity for water conservation and the possibility of reducing water utility bills.

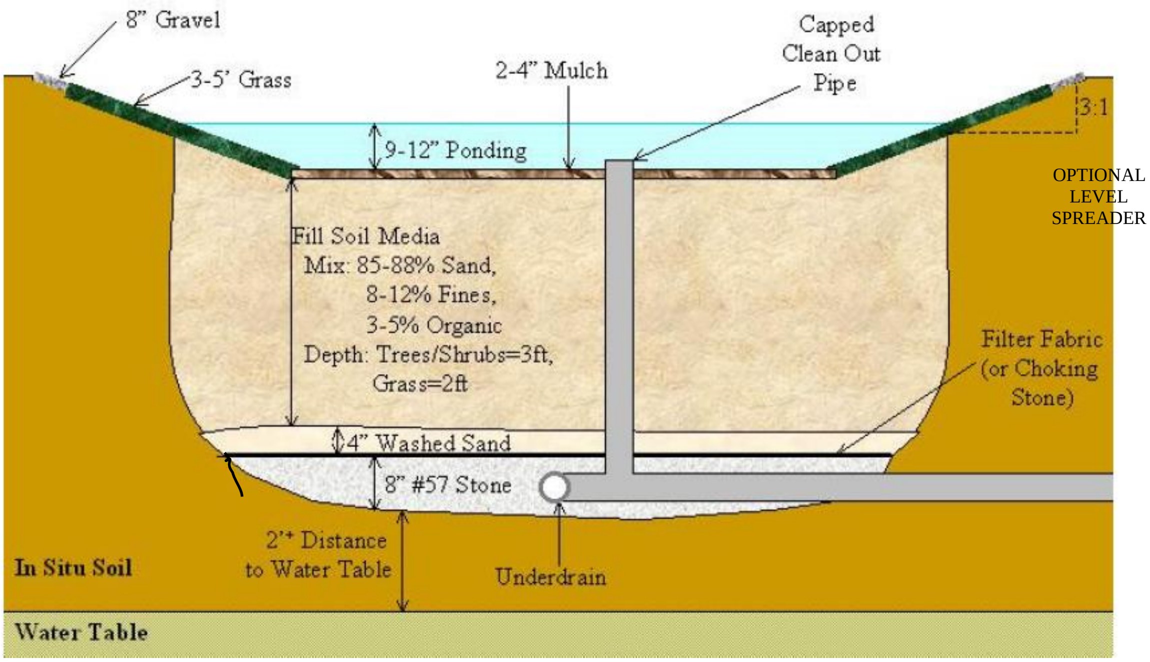


Figure 6.2. Typical Bioretention BMP

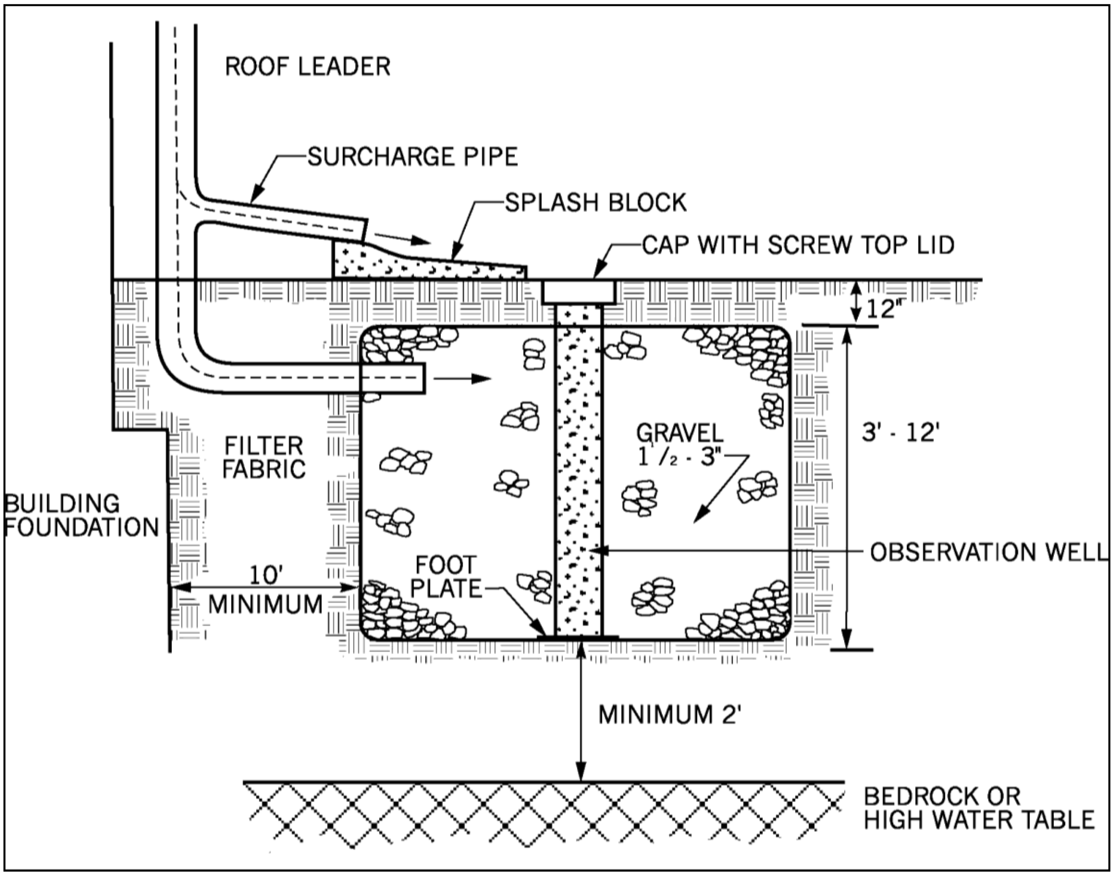


Figure 6.3. Typical Dry Well

Design Considerations: Cisterns are applicable to residential, commercial, and industrial LID sites. Due to the size of rooftops and the amount of imperviousness of the drainage area, increased runoff volume and peak discharge rates for commercial or industrial sites may require larger capacity cisterns. Individual cisterns can be located beneath each downspout, or storage volume can be provided in one large, common cistern. Cisterns should be located where readily accessible in case maintenance or replacement becomes necessary.

- Sand Filters: Sand Filters constructed with a minimum two-foot internal water storage (IWS) layer and soil bottom promote infiltration of storm water run-off into the subsurface are considered LID BMPs. Subsurface soil characteristics such as grain size and hydraulic conductivity affect the rate of infiltration. Construction techniques such as raking or scarifying the in-situ soil can increase infiltration rates.

- Rain Barrels: Rain barrels are low-cost, effective, and easily maintainable retention devices applicable to both residential and commercial/industrial LID sites. Rain barrels operate by retaining a predetermined volume of rooftop runoff (i.e., they provide permanent storage for a design volume); an overflow pipe provides some detention beyond the retention capacity of the rain barrel. Figure 6.4 shows a typical rain barrel. Rain barrels also can be used to store runoff for later reuse in lawn and garden watering. However, water from rain barrels is not to be used for potable use.

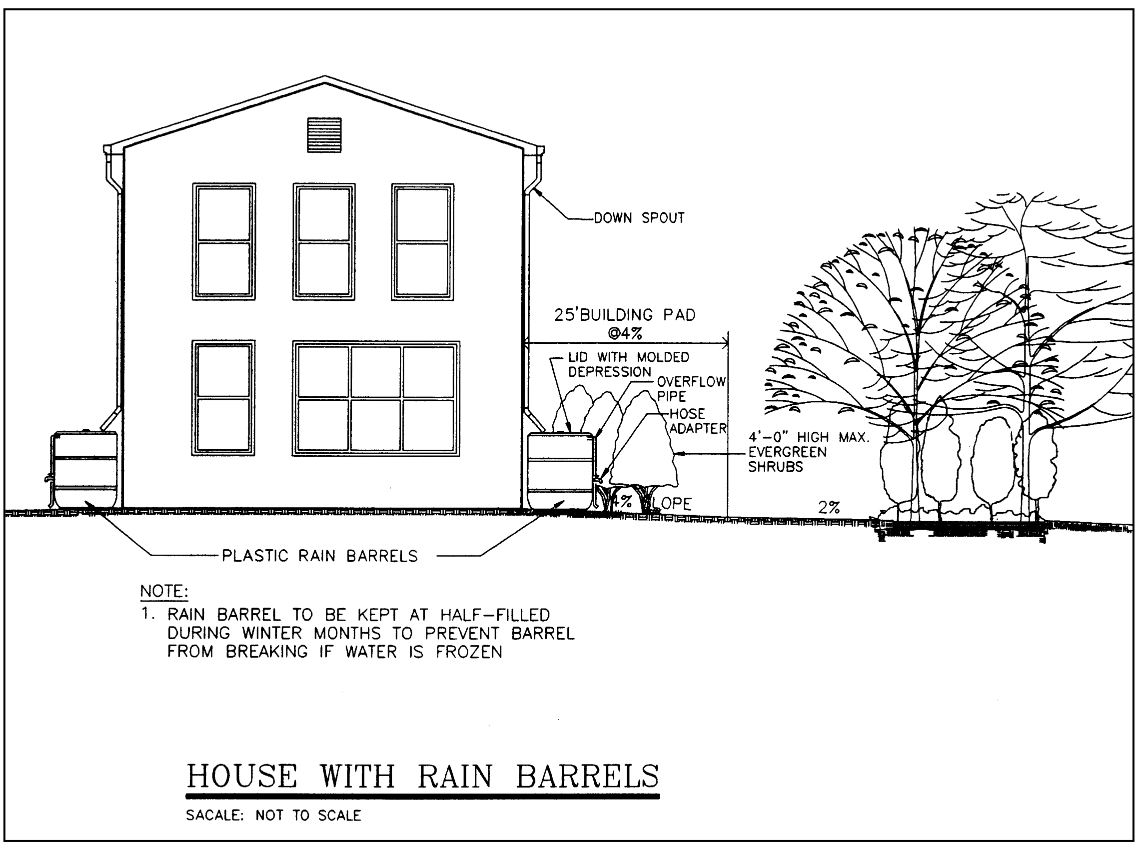


Figure 6.4. Typical Rain Barrel

Design Considerations: Rain water from any type of roofing material may be directed to rain barrels. To be aesthetically acceptable, rain barrels can be incorporated into the lot's landscape plans, or patio or decking designs. Rain barrels placed at each corner of the front side of the house should be landscaped for visual screening. Rain barrels are not allowed within a public right-of-way nor within the required setback, required side yard, or within five (5) feet of an established rear yard as regulated by the Huntersville Zoning Ordinance. Since all rain barrels will be located on private property, they must be included in any private storm water maintenance agreement. Gutters and downspouts are used to convey water from rooftops to rain barrels. Filtration screens should be used on gutters to prevent clogging of debris. Rain barrels should be designed so that complete draining of the BMP is possible. Rain barrels should also be equipped with a drain spigot that has garden hose threading, suitable for connection to a drip irrigation BMP. An overflow adapter could be used to connect two or more barrels to divert surplus water away from foundations. An overflow outlet must be provided to bypass runoff from large storm events. Rain barrels must be designed with removable, child-resistant covers and mosquito screening on water entry holes. The size of the rain barrel is a function of the rooftop surface area that drains to the barrel, as well as the inches of rainfall required for retention storage. For example, one 42-gallon barrel provides 0.5 inch of runoff storage for a rooftop area of approximately 133 square feet.

6.5 Detention BMPs

LID detention BMPs are used to satisfy the detention storage volume requirement calculated in Section 5. As noted in Section 5, the storage required to maintain the pre-development volume using retention might not be adequate to maintain both the pre-development volume and peak flow rate. Therefore, additional detention storage is required in the form of LID detention BMPs. For LID sites, detention BMPs are preferably used in combination with retention BMPs. The ratio of retention storage to detention storage is calculated in Section 5.5.5, Step 6. Detention structures store the volume and then release the discharge through a control structure at the pre-development rate. Some water quality benefit may be realized as pollutants settle out during detention. The SCS Rational Method is used to determine the discharge in order to size the outlet. LID detention BMPs include filter strips, grassed swales, level spreaders, and rooftop storage. (Refer to Table 6.1 for a complete listing.) The following are brief descriptions of some LID detention BMPs:

- Filter Strips: Filter strips are typically bands of close-growing vegetation, usually grass, planted between pollutant source areas and a downstream receiving waterbody. They also can be used as outlet or pretreatment devices for other storm water control practices. For LID sites, a filter strip should be viewed as only one component in a storm water management BMP. Filter strips remove pollutants and help mitigate concentrated peak flows.

  Design Considerations: LID filter strips should be planted in combination with existing natural vegetation to meet the needed filter width. Usually the minimum width for grassed filter areas is 15 feet, while that of wooded areas is 35 feet. Depending on specific site conditions, filter areas may be as wide as 150 feet. The width is based on a required detention. Filter strips function best when they are level in the direction of storm water flow toward the receiving water. This orientation creates proper sheet flow through the strip, increasing infiltration and filtering of sediments and other organic solids. To prevent erosion or channel formation, a level spreader should be situated along the top edge of the strip.

- Grassed Swales: Grassed swales are earthen channels covered with a dense growth of a hardy grass, such as tall fescue. Grassed swales are typically located at the outlets of road culverts, as conveyance between homes, and as highway medians. Swales provide detention storage. They can also provide a water quality benefit if designed for pollutant removal. Design Considerations: Maximum swale depth is to be 2.9 feet, with a maximum head of flow over a private driveway of 0.50 feet. Culvert structures should have a weir located no closer than 1 foot from the inlet to control the peak flow rate. LID swales may be designed with a curvilinear width to maximize storage volume for detention. For LID sites, side slopes outside a right-of-way may be 2:1. Table 6.3 provides design considerations for grassed swales.

Table 6.3. Grassed Swale Design Considerations

Design Storm	10-year storm event
Channel Capacity	Swale must be sized to convey the peak discharge of the 10-year storm event.
Soils	The permeability (infiltration rate) of the soils will determine whether a dry or wet swale can be used. It is recommended that soils used for dry swales have infiltration rates of 0.27 – 0.50 inches per hour.
Channel Shape	Trapezoidal or parabolic shape recommended.
Bottom Width	2 foot minimum, 6 foot maximum.
Side Slopes	3:1 or flatter for mowable slopes in lawn areas.
Channel Longitudinal Slop	1.0% minimum, 6.0% maximum.
Flow Depth	4.0 inches for water quality treatment (maximum).
Manning’s n Value	0.15 for water quality treatment (depth < 4 inches) 0.15 – 0.03 for depths between 4 inches and 12 inches, 0.03 minimum for depth 12 inches.
Flow Velocity	1.0 fps for water quality treatment – 5.0 fps for 2-year and 10-year storms.
Length of Channel	Length necessary for 10 minute residence time.
Maintenance	Routine landscape maintenance required.

- Level Spreaders: A level spreader typically is an outlet designed to convert concentrated runoff to sheet flow and disperse it uniformly across a slope to prevent erosion. The lower edge of the level spreader must be exactly level if the spreader is to work properly. Figure 6.5 shows the design illustration for a level spreader from the NCDENR Design Manual. Design Considerations: Sheet flow, or overland flow, is the movement of runoff in a thin (usually less than 1 inch in depth) layer over a wide surface, which begins when water ponded on the surface of the land becomes deep enough to overcome surface retention forces. Level spreaders can be used to convey sheet flow runoff from lawn areas within graded areas to bioretention facilities and transition areas. They can also be used to deliver runoff from parking lots and other impervious areas to infiltration areas. The receiving area of the outlet must be uniformly sloped and not susceptible to erosion. Particular care must be taken to construct the outlet lip completely level in a stable, undisturbed soil to avoid formation of rilling and channeling. Erosion-resistant matting might be necessary across the outlet lip, depending on expected flows..

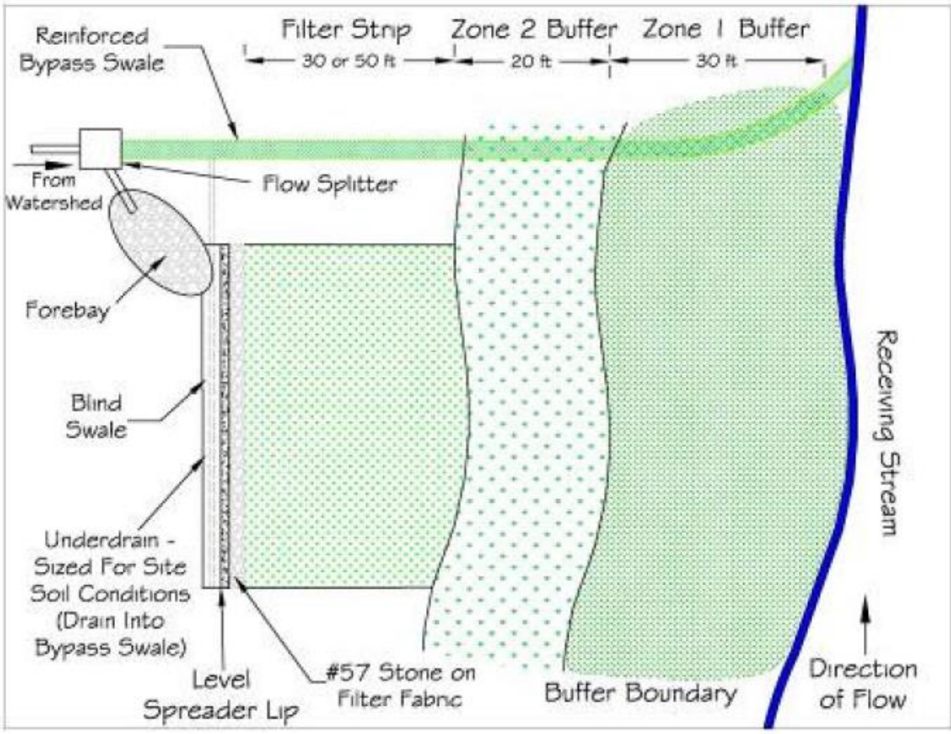


Figure 6.5. NCDENR Level Spreader Design

- Detention Ponds: In some unique circumstances, LID structures will need to be augmented with conventional storm water structures such as dry detention ponds to achieve the Water Quality Target described in Section 4 (see the Charlotte-Mecklenburg Storm Water Design Manual for design specifications). Both dry and wet ponds provide detention storage; however, only wet ponds are effective for water quality purposes.

6.6 Pollution Prevention Practices

Pollution prevention, through public education, implementation of site maintenance and management plans, and industrial process changes, is an integral part of low-impact site development. By emphasizing public education and outreach programs, the site developer can prevent the entrance of pollutants into storm water runoff, thereby reducing the burden on retention and detention BMPs and enhancing their pollutant removal effectiveness. The nature of pollution prevention techniques will complement existing structural controls and will help promote citizen stewardship and local participation in environmental restoration and enhancement efforts.

Section 7. Erosion and Sediment Control Considerations for LID

7.1 Introduction

Erosion and sediment control and storm water management are interrelated. In conventional practice, the design of erosion and sediment controls tend to follow the design of storm water management control BMPs. It is not uncommon to find all of the site area directed to a large sediment control pond, located at the low point of the site. After the site is stabilized, the sediment pond is cleaned out and converted to a storm water management pond. Mass grading operations often disturb more area than is necessary and negative water quality impacts can result from increased soil erosion.

In the application of LID technology the designer must be careful and conscious to carry the LID concepts through to the erosion and sediment control elements of resource protection. If this aspect is overlooked erosion and sediment control problems will be encountered. The application of LID concepts and the associated emphasis on minimizing the areas disturbed, as well as breaking up drainage areas into small manageable subcatchment areas, is consistent with the basic principles of erosion and sediment control outlined below.

7.2 Erosion and Sediment Control Principles

The following six (6) basic commonsense principles govern the development and implementation of a sound erosion and sediment control plan for any land development activity.

1. Planning. Plan the operation to fit the existing site features including; topography, soils, drainage ways, and natural vegetation.
2. Scheduling of Operations. Schedule grading and earthmoving operations to expose the smallest practical area of land for the shortest possible time.
3. Soil Erosion Control. Apply soil erosion control practices as a first line of defense against offsite damage.
4. Sediment Control. Apply sediment control practices as a second line of defense against offsite damage.
5. Maintenance. Implement a thorough maintenance program before, during and after development is completed.
6. Inspection. All erosion and sediment control structures must be inspected at least once a week and within 24 hours (weekends and holidays included) after any storm event >.5 inches of rain per 24 hour period (see Mecklenburg County Soil Erosion and Sedimentation Ordinance).

The following sections describe key elements of the above principles in detail.

7.3 Principle One: Planning

The first principle of erosion and sediment control is to plan the development to fit the site features, including; topography, soils, drainage ways, and natural vegetation. It should be observed that this principle is very similar to the planning guidelines provided for LID in Section 4 of this Design Manual. Listed below are key considerations of the planning element.

Topography. The primary considerations are slope steepness and slope length (see Example 7.1). Due to the runoff effects, longer and steeper slopes provide for the greatest erosion potential. The percent of slope can be determined from site topography. Areas of similar slope can be grouped together to produce a slope area map, which identifies areas of similar steepness. Slope steepness can be grouped into three or more general ranges of erosion potential as listed below:

0 - 7 % - Low erosion hazard (buildable, no constraints)
7 - 15 % - Moderate erosion hazard (moderate building constraints, selective clearing)
15 % or over - High erosion hazard (do not disturb, preserve)

Within these slope ranges, the greater slope length results in a greater the erosion hazard. Therefore, in determining potential critical areas the site planner should be aware of excessively long slopes. As a general rule, the erosion hazard will become critical if slope lengths exceed the following values:

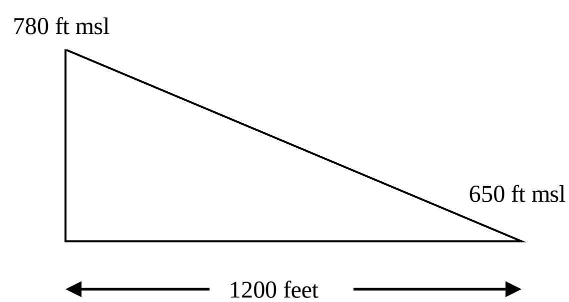
0 - 7 %	-	300 feet
7 - 15 %	-	150 feet
15 % or over	-	75 feet

Example 7.1: Calculation of Slope Steepness and Slope Length

In the sample cross section through a development site at right, the elevation change is 130 feet (780 – 650) and the slope length is 1200 feet. The slope steepness is calculated as follows:

$$\frac{(780-650)}{1200} = 0.025 * 100 = 10.8\%$$

This example results in a moderate erosion potential. However, when the slope length is taken into account, the erosion hazard is considered critical because slope steepness values from 7 – 15 % with slope lengths in excess of 150 feet indicate a critical erosion hazard.



Drainage ways. Natural drainage patterns existing on the site should be identified in order to plan around these critical areas where water will concentrate. Where it is possible natural drainage ways should be used to convey runoff over and off the site to avoid the expense and problems of constructing an artificial drainage BMP. These natural drainage ways should be protected with vegetative buffers whenever possible or required.

Man made ditches, diversions, and waterways will erode if they are not properly stabilized. Care should also be taken to be sure that increased runoff from the site will not erode or flood the existing natural drainage feature.

Soils. Major soil considerations from an erosion and sediment control standpoint include; erodibility, permeability, depth to water table and bedrock, and soils with special hazards including shrink/swell potential or slippage tendencies. The Mecklenburg County Soil Survey provides data on these properties for the soils found in the county.

Erodibility is a term that describes the vulnerability of a soil to erosion. Soil erodibility is influenced by the average particle size and gradation (texture), percentage of organic matter, and soil structure. The most erodible soils generally contain high proportions of silt and very fine sand. The presence of clay or organic matter tends to decrease soil erodibility. Clays are sticky and tend to bind soil particles together, which along with organic matter helps to maintain stable soil structure (aggregates). By combining the soils information with the topography, drainage, and vegetation on the site, the planner can determine the critically erodible and sensitive areas that should be avoided if possible during construction.

Natural Vegetation**.** Ground cover is the most important factor in terms of preventing erosion. Any existing vegetation that can be saved will help prevent erosion. Vegetative cover shields the soil surface from raindrop impact and the root mass holds soil particles in place. Vegetation can "filter" sediment from runoff. Thus grass "buffer strips" can be used to remove sediment from surface runoff. Vegetation also slows the velocity of runoff and helps maintain the infiltration capacity of a soil. Trees and unique vegetation protect the soil as well as beautifying the site after construction. Where existing vegetation cannot be saved, the planner should consider staging construction, temporary seeding, or temporary mulching.

7.4 Principle Two: Scheduling of Operations

The second erosion and sediment control principle is to expose the smallest practical area of land for the shortest possible time. The reason for this principle is that 1 acre of exposed land will yield less sediment than 2 acres of exposed land, and an area exposed for 3 months will yield less sediment than an area exposed for 6 months.

The clearing, grubbing and scalping (mass clearing or grading) of excessively large areas of land at one time promotes erosion and sedimentation problems. As previously described in Section 4 entitled Planning for LID, these initial earth disturbing activities should be kept to a bare minimum. On the areas where disturbance takes place the site designer should consider staging construction, temporary seeding and /or temporary mulching as a technique to reduce erosion. Staging construction involves stabilizing one part of the site before disturbing another. In this way the entire site is not disturbed at once and the duration of soil exposure is minimized. Temporary seeding and mulching involves seeding or mulching areas that would otherwise lie open for long periods of time. The time of exposure is limited and therefore the erosion hazard is reduced.

7.5 Principle Three: Soil Erosion Control Practices

The third important principle is to apply soil erosion control practices as a first line of defense against offsite damage. This principle relates to using practices that control erosion on a disturbed area to prevent excessive sediment from being produced. Control does not begin with the perimeter sediment trap or basin, rather it begins at the source of the sediment and extends down to the control structure.

Soil particles become sediment when they are detached and moved from their initial resting place. This process, which is called erosion, is accomplished for the most part by the impact of falling raindrops and the energy exerted by moving water and wind. A reduction in the rate of soil erosion (Soil Loss) is achieved by controlling the vulnerability of the soil to erosion processes or the vulnerability of the soil to erosion processes, or the capability of moving water to detach soil particles. In humid regions, such as Mecklenburg County, this is accomplished through the use of "soil stabilization" and "runoff control practices".

Soil stabilization practices include a variety of vegetative, chemical, and structural measures used to shield the soil from the impact of raindrops, or to bind the soil in place, thus preventing it from being detached by surface runoff or wind erosion. Approved soil stabilization practices in the North Carolina Erosion and Sediment Control Design Manual under Section 6.10, Surface Stabilization, and includes the following practices:

- Temporary Seeding
- Permanent Seeding
- Sodding
- Trees, Shrubs, Vines, and Ground Covers
- Mulching
- Riprap

Additional guidance can be found in the Charlotte Mecklenburg Land Development Standards Manual, Section 30.17.

The use of mulch to achieve temporary stabilization before permanent vegetation is established is gaining increased attention and recognition. Ongoing research efforts are confirming the fact that mulching is a very effective method of reducing runoff as well as removing pollutants from runoff.

Runoff control practices, in contrast, include a number of measures designed to reduce the amount of runoff that is generated on a construction site, prevent offsite runoff from entering the disturbed area, or slow the runoff moving through and exiting the disturbed area. Drainage system outlet velocities shall not exceed 5 feet per second (fps). Approved runoff control practices are provided in the following Sections of the North Carolina Erosion and Sediment Control Planning and Design Manual:

Section 6.2 – Runoff Control Measures, Provides standards for the following practices: 1) temporary diversions; 2) permanent diversions; 3) diversion dikes (perimeter protection); and 4) right-of-way diversions (water bars).

Section 6.3 – Runoff Conveyance Measures, provides standards for the following practices: 1) grass lined channels; 2) riprap channels; and 3) temporary slope drains.

Section 6.4 – Outlet Protection, provides standards for the following practices: 1) level spreader; and 2) outlet stabilization structure.

Additional guidance is available in the Charlotte-Mecklenburg Land Development Standards Manual.

7.6 Principle Four: Sediment Control Practices

The fourth principle is to apply sediment control practices as a second line of defense against offsite damage. Even with the best erosion control plan, some sediment will be generated and controlling it is the objective of this principle. Whereas soil erosion control practices are designed to prevent soil particles from being detached, sediment control involves using practices that prevent the detached particles from leaving the disturbed area and getting to receiving waterways. This is accomplished by reducing the ability of surface runoff to transport sediment and by containing the sediment onsite.

Sediment control practices are designed to slow the flow of water by spreading, ponding, or filtering. By so doing, the ability of the water to transport sediment is reduced, and sediment settles out of suspension. Commonly used control practices include: 1) the preservation or installation of vegetated buffer areas down slope of the disturbed area to slow and filter the runoff, 2) the construction of small depressions or dikes to catch sediment (particularly coarse-textured material) as close to its point of origin as possible; and 3) the construction of sediment traps or basins at the perimeter of the disturbed area to capture additional sediment from the runoff.

The amount of sediment removed from the runoff is mostly dependent upon (1) the speed at which the water flows through the filter, trap or basin; (2) the length of time the water is detained; and (3) the size, shape and weight of the sediment particles.

Sediment control practices which have been approved for use in North Carolina are presented in the North Carolina Erosion and Sediment Control Planning and Design

Manual under Section 6.60 - Sediment Traps and Barriers, which provides information on the following control devices:

- Temporary Sediment Trap
- Sediment Basin
- Sediment Fence
- Rock Dam

Section 6.5 – Inlet Protection provides standards for the following practices; 1) Excavated Drop Inlet Protection, 2) Fabric Drop Inlet Protection, 3) Block and Gravel Inlet Protection, and 4) Sod Drop Inlet Protection.

Currently, the most frequently used approach to sediment control is simply to direct all surface runoff into a large sediment basin, which is later cleaned out and converted to a storm water management pond. While this approach is arguably the simplest and lowest cost method to control sediment, it often fails to address the other principles described above and thus may not represent the best way to prevent and control sediment.

One of the underlying concepts of LID technology involves breaking up the drainage areas of a given site into very small catchment areas and to provide opportunities to increase the time of concentration and thus reduce peak discharges. Accordingly this approach will benefit sediment control efforts by diffusing surface flow into many directions and providing more flexibility in the use of a variety of sediment control practices.

This approach will provide more opportunity to use silt fences and small traps to control small catchment areas generally in the range of one to three acres in size. It will also allow more opportunity to integrate the use of vegetative buffers in sediment control. When bioretention practices are planned for storm water management, they can first be used as a small temporary trap, by excavating the top two feet of soil. After the site is stabilized, the trap and accumulated silt can be removed and the bioretention cell can be completed. See Section 8.2.1 of this manual for additional information.

7.7 Principles Five and Six: Maintenance and Inspection

The final important control principle is to implement a thorough maintenance and follow up operation. This principle is vital to the success of an erosion and sediment control program. A site cannot be controlled effectively without thorough, periodic checks of all erosion and sediment control practices. When inspections reveal problems, modifications, repairs, cleaning or other maintenance operations must be performed expeditiously.

Particular attention must be paid to water-handling structures such as; 1) diversions, 2) sediment traps, 3) grade control structures, 4) sediment basins, and 5) areas being revegetated. Breaches in the structures or areas being revegetated must be repaired before the next rainfall.

Section 8. Construction and Maintenance

8.1 Introduction

The effectiveness of an LID system is a function of the design and the construction techniques employed. Of these two parameters, construction is far more critical at achieving quality results. Poor construction techniques will cause the best designed BMP to fail prematurely, usually from sedimentation and/or clogging. To prevent this from occurring, adequate and proper inspection is required. This Section covers the basic concepts associated with LID construction and inspection. Refer to the NCDENR Storm Water BMP Manual for specific bioretention design criteria.

8.2 Permitting and Processing

Typically, the installation of bioretention is a component of the grading and storm water management permit associated with the development or individual lot. Conceptual storm water management approval and construction permits have already been obtained by this point and are not covered here. For specific permitting information, contact Mecklenburg County Land Use and Environmental Services Agency (LUESA).

8.3 Erosion and Sediment Control Principles for Bioretention Applications

During the construction phase, sedimentation and erosion problems can be greatest due to exposed earth, clearing and grubbing operations, and equipment soil compaction. For this reason, erosion and sediment controls are required to contain sediment onsite. For conventional storm water management design, this meant that the designer simply had to place a sediment control pond at the lowest point of the property under development. The sediment basin would then be used for storm water management control after construction was completed. Sites that incorporate bioretention for storm water control require closer attention to detail because drainage areas are reduced and massive site grading to one low point is discouraged. As a result, grading and sediment control practices are typically applied on a lot-by-lot basis to minimize the opportunity for soil transport. The following principles are identified and briefly explained for the user of this manual.

<u>Principle 1:</u> Planning and phasing. **PRIOR** to construction and even design, proper planning for sediment control is needed for each lot. Bioretention is a source BMP that requires placement within the lot area or common open space area. Therefore, when laying out the development, the designer must analyze the topography, existing tree cover to be preserved, the building location and associated setbacks, slope steepness and length, drainage ways, and soil types.

<u>Principle 2:</u> Schedule of Operations. Expose the smallest area of land for the shortest possible time. All sediment control devices must be in place prior to the start of the main construction. At the end of each workday, inspect the devices to be sure of their adequacy and safeguard any trenches or excavations. Provide temporary stabilization for disturbed areas as quickly as possible or as directed by the inspector. Areas that have been disturbed and are not actively being worked, as well as areas that are on final grade, must be stabilized within 14 days.

Principle 3: Soil Erosion Control. This is the first line of defense against contamination of the bioretention area. This would include the installation of on-lot silt fences, diversion swales, stabilization and runoff control techniques. Make sure that silt fencing is properly keyed into the ground to prevent undermining. See the Charlotte Mecklenburg Land Development Standards for guidance.

Principle 4: Sediment Control. Even with the best erosion control techniques, sediment transport will occur. For this reason, on-lot sediment traps and/or super silt fence control practices are recommended.

Principle 5**:** Inspection and Maintenance. Erosion and sediment control practices must be inspected and maintained on a routine schedule. Accumulated sediment must be removed on a periodic basis, and inspected for excessive accumulation after every major storm. Particular attention should be paid to the stabilization of disturbed areas and integrity of the sediment control devices. All sediment traps must have room for additional sediment loading capacity. Proper disposal of removed sediment is imperative to reduce the probability of downstream contamination.

Sedimentation Rates for Bioretention. Although no specific sedimentation studies have been done on bioretention to determine the rate of accumulated sediment, estimated vertical settling rates may be derived from Stokes Law. Sedimentation rates will vary significantly and are a function of the following factors:

- Soil Particle size distribution and load of the influent (affected by land use activities)
- Retention time in the ponded area Physical features of the bioretention facility surface and resulting flowpath length
- Surface area
- Water temperature affecting fluid viscosity
- Wind resuspension (minimal effect)

8.4 Construction Technique and Sequencing for Bioretention

8.4.1 Site Preparation and Planning

Most importantly, the erosion and sediment control principles discussed in Section 7 must be followed to insure sediment will not affect the BMP. In the planning and lot layout phase, the potential bioretention locations are identified. Bioretention facilities should be located within the development envelope, minimizing the need to clear areas unnecessarily. Bioretention areas may make use of existing wooded areas, with minimal clearing required. The BMP must be located on commonly owned property such as property owned by the Homeowners' Association. BMPs are not to be located on private property due to concerns regarding proper maintenance. Any deviation from this policy must be approved by the Storm Water Administrator.

Two methods of sediment control are typically applied to bioretention facilities as follows.

Method One

The first method (most typical) is to avoid disturbing the proposed bioretention area after the initial rough grading and temporary stabilization has been performed. During the construction phase, all drainage must be directed away from the BMP location to avoid excessive sedimentation. Flow can be directed away from the bioretention BMP by utilizing silt fencing materials and temporary diversion swales that direct flows to small on-lot silt traps.

Method Two

The second method of erosion and sediment control design allows the area proposed for the bioretention BMP to be used for the installation of a sediment control structure. If a sediment control structure is to become a bioretention BMP, the following conditions must be met:

- The proposed invert of the bioretention BMP must be greater than 1 foot below the invert for the sediment control structure.
- All remnant sediment must be removed.
- If geotechnical tests show that the in-situ soils meet or exceed the soil medium guidelines for infiltration rates (see section 8.4.10), no underdrain will be required, although it is still highly recommended.
- The in-situ soils and ponded sediment materials shall be removed and the remaining surface scarified to increase the likelihood of adequate infiltration potential.

8.4.2 Design Considerations

Bioretention facilities must be designed and sized to treat runoff from the first inch of rainfall and must bypass larger flows to prevent disruption of plants, mulch and soil media. It is difficult to maintain sheet flow conditions for these larger flows, which oftentimes can lead to clogging of outlet structures or increased maintenance of the bioretention facility. It is important to insure that inflow velocity is dissipated and dispersed such that sheet flow (even spread of inflow) is created. Sheet flow allows for low water velocity to be evenly distributed into the facility thus causing little to no disruption of plants, mulch or soil media. This improves the overall functionality of the bioretention facility, decreases maintenance and prolongs the life of the device. Sheet flow can be achieved in a variety of ways including:

1. Plunge pool/sediment forebay (shallow) to reduce inflow velocities.
   - Ensure 3:1 side slopes and design for the appropriate entry volume and velocity.
   - Discharge rim of pool or forebay should be level for even distribution into the device (use uniform stone or structural weir).
   - Use pipe with reverse flow. Water channeled into the pipe is discharged via the lateral openings in the pipe.
2. Level spreader (flush curb, structural weir, lateral grass swale)
3. Indirect discharge from overland flow, parking lot, various sheet flow. It is extremely important to avoid all direct discharges to the bioretention facility from flumes, swales, pipes, downspouts, etc. unless one of the above methods or other similar level spreading device is utilized. A forebay is an effective device for dispersing inflow velocity. A forebay will also act to settle out sediment from the inflow which will protect the bioretention area from clogging. However, if a forebay is installed it will need to be inspected at least monthly and accumulated sediment removed as necessary. Depending on the type of forebay liner material (rip rap/concrete) be sure to construct a level outlet to prevent the re-concentration of flow and maintain sheet flow. If using rip rap, a smaller stone may be warranted to fill outlet voids between larger stones to reduce multiple point discharges.

Another important design consideration for a bioretention facility is to provide 100% ground cover around the perimeter of the facility. Bare ground contributes directly to sediment runoff which clogs the bioretention facility thus preventing it from functioning properly. Two instant ground cover solutions are sodding and mulching. Seeding and matting may also be used with the addition of silt fence around the entire perimeter of the bioretention facility to prevent sediment entry during seed germination. The application of ground cover around the perimeter of the bioretention facility should occur after the excavation of the basin and prior to the installation of the underdrain or soil media. Access points should be included to allow for the completion of construction activities.

Tall grasses can also be an effective tool for controlling velocity and sediment. These grasses can be located along the edge of the bioretention facility at the point of inflow to slow velocities and filter particles.

When utilizing a direct entry from curbing via a curb cut, rip rap is generally installed at the inlet of the bioretention facility for velocity control. For effective use, the rip rap should be "keyed" below the invert of the curb line to allow for positive flow into the facility without the potential for bypass to occur due to buildup of sediment along the curbline.

When entry slopes of 3:1 or less cannot be achieved due to elevation constraints, a drop structure should be considered to avoid potential slope failures. In addition, sheet flow should be re-introduced at the outlet using the previous examples in numbers 1, 2, 3, or 4 above.

Soil compaction tests are required on any berms $\geq$5 feet in height from the natural grade. Soil compaction must be at 95% proctor and certified by a licensed soil engineer.

8.4.3 Minimize Lot Grading/Clearing

Bioretention facilities should be located within the development envelope, minimizing the need to clear areas unnecessarily. Bioretention areas may make use of existing wooded areas, without grading the wooded area to install the facility. Grading of any catchment area draining to the facility should be done sparingly and stabilized immediately (within 14 days).

8.4.4 Install Sediment Control and Diversion Devices

Install the necessary sediment control devices to protect the facility from contamination by sediment by following the approved sediment and erosion control plan. Essentially, the placement of silt fence material around the perimeter should be sufficient to prevent flow from entering the area during construction. If the inspector approves the installation of bioretention facilities prior to the final asphalt coat, flow diversion devices must be installed to prevent storm water flow into the BMPs. This is essential because this flow will likely contain fine soil particles that will clog the media in the bioretention facility thus rendering it ineffective.

8.4.5 Excavation Preparation

Excavate the facility to the design specifications. Excavated materials must be placed away from the facility sides to avoid contamination and possible side wall instability. Large tree roots (>2 inches in diameter) must be trimmed flush with the trench bottom. The sidewalls of the trench must be roughened where sheared and sealed by heavy equipment.

8.4.6 Underdrain Specification

Underdrains are required on all bioretention BMPs. The underdrain system (pipe capacity and orifice capacity) must be designed assuming that 50 percent of the capacity is lost due to clogging. The following information provides guidance for underdrain installation.

Location. Underdrains are typically located at the invert of the bioretention BMP to capture and remove any filtered water that does not infiltrate into the surrounding soils. The underdrain is placed at the bottom of the excavated trench under a 12-inch gravel layer, 4 feet in width (minimum) with at least 4 inches of gravel above the top of the pipe. If multiple underdrain pipes are used, they must be spaced at a maximum of 10 feet on center. Soil over the gravel layer must be at least 2 feet in depth and up to 4 feet if trees are planted. Placement of 2 to 3 inches of gravel bedding is recommended beneath the discharge points. Underdrains must "daylight" or connect to an existing drainage system and achieve a positive flow condition (minimum of 2.5 feet per second flow velocity for full flow conditions or 0.5% slope). Prior to covering the underdrain system, the inspector must observe the underdrain itself, the connections and the gravel bedding. Suitable discharge points include:

- Grass swale areas, flush cut with side slope areas.
- Storm drain pipe conveyance system.

Underdrain Material Types**.** Underdrain systems may be composed of a variety of materials. Double wall HDPE corrugated plastic pipe is recommended due to its rigidness and long life expectancy. Other pipe materials may be substituted at the designer's prerogative and with the inspector's approval such as 6-inch PVC pipe. All underdrain pipes must be a minimum of 6 inches in diameter.

Connections. Pipe joints and storm drain structure connections must be adequately sealed to avoid leaks. Pipe sections must be coupled using suitable connection rings and flanges. Field connections to storm drain structures and pipes must be sealed with polymer grout material that is capable of adhering to surfaces. The underdrain pipe must be capped until site completion.

Perforations. Perforated PVC pipe sections are available from local hardware and building supply stores. The perforation locations are not critical for proper operation, as long as the total opening area exceeds the expected flow capacity of the underdrain itself. Commonly marketed perforated PVC pipe has ¼ to ½ inch perforations, 6 inches from center to center, along two or three longitudinal rows. Whether or not the perforations are placed at the invert of the pipe or elsewhere, depends upon the design of the facility. Typically, the perforations are placed closest to the invert of the pipe to achieve maximum potential for draining the facility. The perforations can be placed near the top of the pipe if an anaerobic zone is intended. Water below the perforated portion of the underdrain will have a tendency to accumulate during periods of saturation. Otherwise, water will have a tendency to infiltrate into the surrounding in-situ soils.

8.4.7 Observation/Cleanout Standpipe

An observation/cleanout standpipe must be installed to the underdrain in every bioretention BMP. The standpipe will serve two primary functions: 1) it will indicate how quickly the bioretention BMP dewaters following a storm; and 2) it provides a maintenance port. The cleanout standpipe must be located at the upper end of the structure and be capped above the water level elevation. It must consist of a rigid, non-perforated PVC pipe, 6 inches in diameter. A cleanout must be installed at both ends of the system and at all bends. If the bioretention BMP exceeds 100 feet in length; additional cleanouts must be installed in series every 50 feet. The top of the cleanout must be capped with a screw, or flange type cover to discourage vandalism and tampering. Locking is not necessary.

8.4.8 Gravel Bed

Gravel bed materials are used to protect an underdrain pipe to reduce clogging potential. Placement of the gravel over the underdrain must be done with care. Avoid dropping the gravel from a backhoe at elevated heights. Spill gravel gently over the underdrain and spread manually. The gravel stone size shall be no greater than ½ to1½ inches in diameter (blue stone, double washed, #57 stone). The depth of the gravel must not exceed 12 inches.

8.4.9 Choking Stone and Sand

The designer must specify a layer of #8 or #89 choking stone as provided in Chapter 12 of NCDENR's BMP Design Manual. The stone layer shall be at least 2-inches thick. The next layer shall consist of 4 inches of washed sand per Chapter 12 of NCDENR's BMP Design Manual.
A four-inch layer of washed sand or equivalent must be placed over the filter fabric or choking stone to further reduce the potential for fines reaching the underdrain.

8.4.10 Soil Media Preparation and Installation

Soil media specifications for proposed bioretention sites are required and must be submitted as part of the Preliminary Plans. Soil preparation can be accomplished by thoroughly mixing soil components, amendments and additives, as needed utilizing a backhoe or front-end loader. Table 8.1 contains the specifications for the soil mixture to be used in a bioretention facility. Test methods are specified for all parameters except sand and clay content but tests are required only for total phosphorus and particle size for the soil media mix. However, the inspector may at their discretion test suspected soil media for any of the parameters indicated in Table 8.1 and disapprove it for use if results do not meet the acceptable values. A Soil Verification Form (see Appendix E) must be filled out and notarized to verify that total phosphorus and particle size tests have been performed and that results are within the acceptable values indicated in Table 8.1. This form must be provided to the County inspector prior to the placement of the soil in the bioretention facility. Soil preparation can be performed off-site and transported to the facility location when ready for installation. In these situations, the Soil Verification Form must be approved by the inspector prior to bringing the soil on-site. In all situations, the County inspector must inspect the soil on-site prior to installation.

Soil must not be installed until all of the contributing drainage area has been stabilized and approved by the inspector. Provisions for sediment control must be installed and maintained as specified in the sediment and erosion control plans. Soil should not be delivered to the site until excavation has taken place and the fabric and underdrain system has been installed. Scarification of in-situ soil surfaces by manually raking to aerate and reduce soil compaction is recommended.

Table 8.1. Specifications for the Soil Mixture in Bioretention Facilities

(1) Even though testing is not required for all parameters, the inspector reserves the right to test suspect material and disapprove it for use if results show that parameters do not meet the acceptable values.

(2) Phosphorus Index test methods are based on information received from Dr. Myers at the N.C. Department of Agriculture.

Parameter	Acceptable Values		Testing Required (1)	Test Method
Sand Content (ASTM C-144 recommended)	80%		No	None
Organic Material (compost, sandy loam and loamy sand)	20%		No	TMECC 05.07-A
Clay Content	Less than 6%		No	None
Phosphorus Index (total Phosphorus) (2)	10 to 30 (12 to 36 ppm on a dry basis)		**<u>Yes</u>**	Mehlich 3 Extraction, Mehlich 2 Extraction (Mehlich 1 Extraction is acceptable but result must be multiplied by 1.7 for comparison)
pH	5.5 to 7.0		No	TMECC 04.11-A
Permeability	1 to 4 in/hr		No	ASTM D2434 (compacted to 20%)
Particle Size Analysis	Acceptable Minimum % Passing by Weight		**<u>Yes</u>**	ASTM D422
	Lower	Upper		
Sieve 2 inch (50 mm)	100	100		
Sieve No. 4 (4.75 mm)	98	100		
Sieve No. 8 (2.36 mm)	95	100		
Sieve No. 10 (2.0 mm)	86	100		
Sieve No. 16 (1.18 mm)	70	100		
Sieve No. 30 (600 um)	40	75		
Sieve No. 50 (300 um)	10	35		
Sieve No. 100 (150 um)	2	15		
Sieve No. 200 (75 um)	0	5		

Installation of soils must be done in a manner that will ensure adequate filtration. After the invert area of the proposed facility has been scarified, soil should be applied in lifts of 12 inches. This will minimize compaction and application time. Lifts may be applied using a small track machine with low ground pressure such as a minihoe. The lifts may be lightly watered to encourage natural compaction. Removing overfill is easier than adding soil when attempting to bring the facility to the correct elevation. Avoid over compaction by allowing time for natural compaction and settlement. No additional manual compaction of soil is necessary. Rake soil material as needed to level out. It is recommendation that consolidation be allowed to occur followed by the application of additional soil material to bring the facility to the design elevation. Depending upon the soil material, up to 20% natural compaction may occur. In order to speed up the natural compaction process, presoaking the placed soil may be performed. Significant settlement can occur after the first presoak, and additional settlement may occur subsequent to the initial wetting. If time and construction scheduling permits, it is preferable to allow natural settlement to occur with the help of rain events to presoak the soil media. The surface of the facility does not have to be uniform. A slight variation due to settling or mulch application is acceptable as long as the possible ponding does not exceed 12 inches. For areas where excessive settlement occurs, apply sand to fill low areas and check to insure the entire surface is level before planting and mulching the area.

In-situ (or in-place) soil used for bioretention must also be prepared. Scarification of the soil surfaces by manually raking to aerate and reduce soil compaction is recommended. When in-situ soils are being proposed for use, soils investigation/geotechnical reports are required. A copy of the geotechnical report shall be supplied to the inspector at the pre-construction meeting. The report shall include the boring location at the bioretention facility and include USDA soil classification, boring log with penetration depths at least 2' below the proposed facility invert, depth to groundwater or impervious layer (if present), and infiltration rate of the in-situ soil. The bioretention facility shall not be placed in service until all of the contributing drainage area has been stabilized and approved by the inspector. Provisions for sediment control shall be in-place as specified within the sediment and erosion control plans.

Delivery of materials such as soil medium, plants, gravel, sand,, and underdrains will need to be coordinated to avoid stockpiling and contamination problems. Soil materials should not be delivered until the bioretention facility has been excavated or graded to the design elevations and filter fabrics and underdrain systems are in place. A primary reason for bioretention BMP failure is the clogging of the soil mix with fine clays from soil erosion during site installation. To avoid this problem, silt fence should be installed around the entire perimeter of the basin until ground cover is fully established (see Figure 8.1). An alternative would be to use sod to stabilize the soil around the perimeter of the basin. Planting materials should not be delivered until after the soil medium has had time to settle and trimmed to the proper grade elevation. Weather and seasonal conditions will also affect planting requirements.

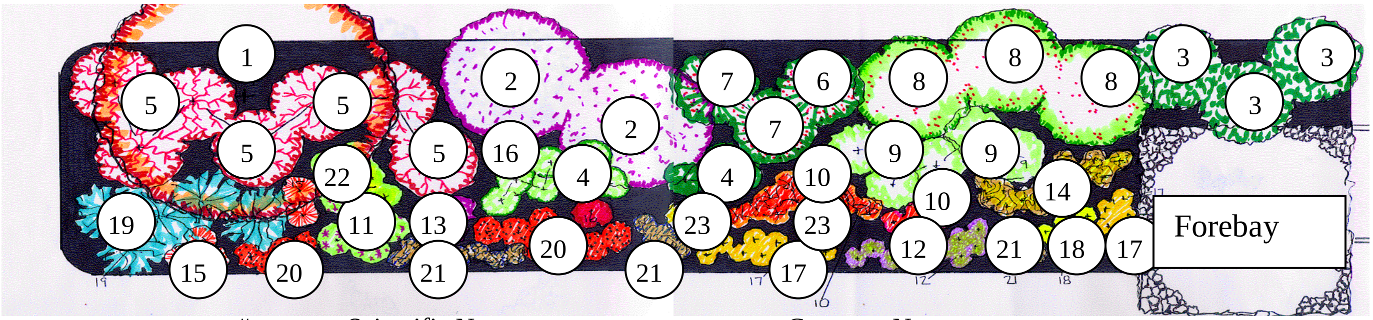
Figure 8.1. Silt Fence Around the Perimeter to Protect From Sedimentation

8.4.11 Plant Preparation and Planting Methodology

When ordering plants to be installed in a bioretention BMP, adequate preparation of the bedding soils must occur prior to delivery. Timing in relation to season and readiness of the BMP is very important. The recommended ordering times for plants are early spring or fall, depending upon the species selected. Often times, plant materials need to be stockpiled while the BMP is being prepared. Keeping root balls wet during this period, and providing a shaded storage location will improve the plants survivability.

The initial density of the planting arrangement will be thick. This is to ensure that adequate vegetative cover will quickly take hold. Once the plants continue to grow and spread out, some plants may be removed or divided by the property owner and transplanted elsewhere. Refer to Design Manual indicated in Table 6.1 for specific species requirements. Selected plants must be able to survive in the soil media mixture.

A minimum of three (3) species of trees and three (3) species of shrubs should be selected to insure diversity. In addition to reducing the potential for monoculture mortality concerns, a diversity of trees and shrubs with differing rates of transpiration may ensure a more constant rate of evapotranspiration and nutrient and pollutant uptake throughout the growing season. To add interest to the rain garden, a variety of plant material should be selected to provide blooming and color at different times of the year. Figure 8.2 illustrates the planting design used at a rain garden installed in November 2003 at the Mecklenburg County Hal Marshall Building located at 700 N. Tryon Street in Charlotte. The rain garden was removed in 2016 to make way for an expansion of Charlotte's Light Rail system. During its 13 years of operation, the rain garden was monitored on numerous occasions and was determined to provide excellent pollutant removal. An assessment performed by N.C. State University determined that the Hal Marshall rain garden provided the highest pollutant removal efficiency of any of the rain gardens being monitored across the State. In addition, maintenance costs for the rain garden were very low.



#	Scientific Name	Common Name
Trees		
1	Acer rubrum	Red Maple
2	Myrica cerifera	Wax Myrtle
3	Magnolia virginiana	Sweet Bay Magnolia
Shrubs		
4	Clethra alnifolia	Hummingbird Clethra
5	Cornus serecia	Red Twig Dogwood
6	Ilex verticillata – male	Deciduous Holly
7	Ilex verticillata	Winter Red Deciduous Holly
8	Ilex vomitoria 'pendula'	Weeping Yaupon Holly
9	Itea virginica	Henry's Garnet Sweetspire
Herbaceous Plants		
10	Andropogon glomeratus	Bushy Bluestem
11	Aster nova-angliea	New England Aster
12	Aster oblongifolius	October Skies
13	Aster tataricus	
14	Chasmanthium latifolium	River Oats
15	Helianthus angustifolia	Swamp Sunflower
16	Hibiscus coccineus	Red Hibiscus
17	Iris virginicus	Blue Flag Iris
18	Oenothera fruticosa	Sundrops
19	Panicum virgatum	Heavy Metal Switchgrass
20	Rudbeckia fulgida var. fulgida	Balck-eyed Susan
21	Schizachyrium scoparium	Little Bluestem
22	Silphium perfoliatum	Cup Plant
23	Solidago rugosa	Fireworks Rough-leafed Goldenrod

Figure 8.2. Hal Marshall Rain Garden Planting Design

Shipping of the plant materials is typically the responsibility of the nursery or landscaping contractor. It is preferable to have the plants shipped directly to the facility site ready for planting.

All plant materials shall be tagged for easy identification with the American Standard for Nursery Stock. Tags shall be checked by the inspector for compliance with the landscaping planting list shown on the design plans or Storm Water Management Permit Application plans. Approved plants for use in bioretention BMPs are provided in the Design Manual reference in Table 6.1 of this manual. Variations of plant type, quantity or quality, requires Mecklenburg County L.U.E.S.A. approval and may necessitate a plan revision submittal.

The number of tree and shrub plantings may vary, especially in areas where aesthetics and visibility are vital to the site development, and should be determined on an individual site basis. Per NCDENR's BMP Design Manual, a minimum of one (1) tree, three (3) shrubs, and three (3) herbaceous species should be incorporated in the bioretention planting plan. A minimum planting density of 400 stems/acre is required.

Plant stock sizes are specified in Chapter 12 of NCDENR's BMP Design Manual. Fertilizer should be used very sparingly and only during installation.

8.4.12 Installation of Mulching Materials

Mulch should be placed on the surface ponding area of the BMP. The mulch material should be fresh, double ground and **screened** hardwood to help retain soil moisture and maximize nutrient uptake. This type of mulch material also helps resist flotation when BMP is fully ponded. Select your mulch carefully. Mulch cannot contain soil or fine organics, which have a tendency to create a barrier to infiltration thus the importance of making sure the mulch is "screened" to remove these fines. Do not use pine straw mulch.

The layer of mulch should not exceed 3 inches in depth. Greater depths keep plant roots from making good contact with the soil. Mulch materials should not be mounded around the base of tree trunks as this practice encourages pests and diseases. The mulch layer should be placed after the plants and groundcover have been installed. Protect and lift groundcover vegetation to place mulch material underneath and between plantings. The mulch layer surface should approximate the final elevation as shown on the design plans. Figure 8.3 shows the rain garden constructed at the Hal Marshall Building parking lot after installation of hardwood mulch.

Figure 8.3. Planted and Mulched Rain Garden

8.5 Maintenance and Operation

8.5.1 Maintenance Access

Adequate access must be provided into all BMP areas for inspection, maintenance, and landscaping upkeep. A 20-foot wide permanent maintenance access easement from a public right-of-way must be provided for all BMPs. The cleared access area within this easement must have a minimum stabilized width of 12 feet, maximum longitudinal grade of 15 percent, and maximum cross slope of 5 percent. In addition, a 10-foot wide permanent maintenance access easement must be provided around the perimeter of all BMPs to allow for adequate maintenance and repair.

8.5.2 Maintenance Requirements for all BMPs

BMPs shall be maintained by the owner of the subject property. The following requirements shall be met for all BMPs that have been constructed on privately-owned property and not within a public easement.

1. Maintenance Covenants. Prior to plan approval and issuance of a storm water management permit, the applicant or owner of the BMP shall establish a formal Maintenance Covenant approved by the Mecklenburg County Land Use and Environmental Services Agency and recorded in the Office of the Register of Deeds in which the owner acknowledges the duty of the owner and all subsequent owners of the property to maintain the BMP in accordance with the terms of the Covenant. A maintenance plan and schedule shall be included as part of the covenant as well as a mechanism for funding maintenance and repairs. This Maintenance Covenant shall also specify the Homeowners Association or other party responsible for maintenance of the BMP. A Homeowners Association or similar legal entity has the power to compel contributions from residents of a development to cover their proportionate shares of the costs associated with BMP maintenance. Examples of a typical Maintenance Covenant, Maintenance Plan and Inspection Checklist are provided in the Administrative Manual for implementation of the Post-Construction Storm Water Ordinance. This Manual is available on the following website: http://stormwater.charmeck.org (select "Regulations", select "Post-Construction Programs & Manuals", select "Mecklenburg County, Towns of Cornelius, Davidson, Matthews, Mint Hill, Huntersville & Pineville", select "Post-Construction Administrative Manual – County and Towns").
2. Requirements for the Maintenance Covenants. BMPs shall be inspected at a minimum of annually by a qualified professional as described in the Maintenance Covenant. The purpose of this inspection is to identify maintenance and repair needs to ensure the long-term functionality of the BMP. Any identified maintenance and/or repair needs shall be addressed in a timely manner. The inspection and maintenance requirement may be increased as deemed necessary by Mecklenburg County Land Development to ensure proper functioning of the BMP.
3. Records of Installation and Maintenance Activities. Parties responsible for the inspection, operation, and maintenance of a BMP shall maintain records of the installation of all the maintenance and repairs and shall retain the records for the life of the BMP. After inspections and maintenance have been performed, a copy of the inspection checklist shall be forwarded by the owner to MCWQP within two weeks of the inspection. The Administrative Manual for implementation of the Post-Construction Storm Water Ordinance contains an example of a typical inspection checklist. This Manual is available on the following website: http://stormwater.charmeck.org (select "Regulations", select "Post-Construction Programs & Manuals", select "Mecklenburg County, Towns of Cornelius, Davidson, Matthews, Mint Hill, Huntersville & Pineville", select "Post-Construction Administrative Manual – County and Towns").MCWQP staff will file submitted inspection forms and enter the inspection information into a BMP maintenance data base to track inspections and maintenance performed. All inspection checklists are to be mailed to 2145 Suttle Avenue, Charlotte, N.C. 28208-5237, Attention: Mecklenburg County Land Development.

Watering and maintenance responsibilities during different phases of a project shall generally be defined as follows, unless contractual obligations require otherwise:

- Construction Phase: Developer/Builder
- Project Acceptance: Builder
- Property Ownership Transfer: Builder/Property Owner
- Warrantee Phase: Property Owner
- Operation Phase: Property Owner/Homeowners Association

8.5.3 Special Maintenance Requirements for Bioretention Facilities

In traditional, intensively cropped landscapes, soil fertility (and especially the level of available nitrogen) is considered the limiting factor to plant growth. By design, bioretention facilities are located in areas where nutrients (especially nitrogen) are significantly elevated above natural levels. Therefore, it is unlikely that soil fertility will be the limiting factor in plant growth, and thus fertilization would be unnecessary. Excess fertilization, (besides compromising the BMP's pollutant reduction effectiveness) leads to weak plant growth, promotes disease and pest outbreaks, and inhibits soil life. If soil fertility is in doubt, a simple soil test can resolve the question. Persons responsible for maintenance may consult with their local nursery or contact the Mecklenburg County Cooperative Extension Office to determine fertility needs. If fertilization should become necessary, an organic fertilizer will provide nutrients as needed without disrupting soil life.

Like any garden area that includes grasses or woody plant materials, harvesting and pruning of excess growth will need to be done occasionally. Trimmed materials may be recycled back in with replenished mulch material. Mulch should be inspected after every significant precipitation event and replaced as necessary. In most cases, shredded mulch should only need replacement once per year.

Typically, watering of the BMP will not be necessary once plants have become established, except during drought conditions. Plant species for bioretention have been selected based on their hardiness and ability to survive extreme conditions. However, watering will be needed during the plant establishment stage. As with any landscaping feature, the designer should consider effects on moisture condition and the ability of the owner to apply watering as needed. Facilities susceptible to drying conditions include:

- Landscape parking lot islands
- Median areas
- Windy, exposed areas

Weeding of the facilities is not absolutely necessary for the proper functioning of the bioretention BMP. However, unwanted plants can be invasive, consuming the intended planting and destroying the aesthetic appeal. Therefore, weeding is encouraged to control growth of unwanted plants, especially where facilities are placed in prominent settings.

<u>Seasonal Care</u>

Spring:

- Prune deciduous trees and shrubs before leaves appear (usually early to mid-March).
- Prune flowering trees and shrubs after blossoming (usually early June).
- Divide ornamental grasses and perennials as soon as the soil becomes soft.

Summer:

- During extended drought, water deeply in the morning every seven to ten days.
- Check trees and shrubs for signs of disease or insect pests. Plant diseases usually can be easily treated when detected early.
- Weed regularly, preferably by hand.

Fall:

- Cut perennials back to the ground after the first frost and remove annuals.

- Plant new trees and shrubs as long as the soil temperature remains above 32 degrees.
- Mulch trees and shrubs to help conditions the soil for spring and to protect roots.

Winter:

- Cut back ornamental grasses and remove clippings.

Troubleshooting Problems

- Look for signs that plants are too wet including wilting, yellowing, ringed spots on leaves, and a soft or rotting base.
- If erosion is occurring at drainage paths, stabilize the erosion.
- If plants are dying, plants more tolerant of drier/wetter conditions may be necessary.
- If water is not dissipating within a couple of days, the BMP is not functioning properly. Water will pond longer in winter and early spring.
- Do not walk or mow in ponding areas.

8.5.4 Warrantees

The landscaping work and materials shall be guaranteed by the developer/builder for one year from the date of the final approval. After one year the property owner will assume responsibility for all landscaping work and materials and shall replace plants if they die.

8.6 Typical Sequence of Construction for Bioretention

The sequence of construction for bioretention areas is closely tied to the grading plans for the development. Because bioretention is a source control BMP, drainage area catchments are kept relatively small and manageable during the construction phase for control of sediment. Basic sediment control practices are employed for each lot.

A typical sequence of construction with a typical construction schedule is provided in Figure 8.4 of this document. The sequence of construction will vary for every project but the designer may utilize this sequence of construction as a general guide. Variations to the sequence must be noted and conveyed to the County inspector. The sequence of construction shall be placed on the plans.

8.6.1 Inspectors Checklist for Bioretention

The following checklist has been developed for use when evaluating a bioretention facility during different phases:

Bioretention Inspection Checklist

1. Pre-construction Meeting

- ➢ Two copies of approved Storm Water Management Plan with Latitude & Longitude of BMPs
- ➢ Submit one copy to Mecklenburg County Water Quality Program for BMP mapping
- ➢ Disseminate inspection requirements; what needs inspection
- ➢ Ticket and tag requirements & a copy of the geotechnical report (if available)

2. Excavation of Bioretention Area

- Soil Permeability
- Suitable sub-grade materials
- Presence of moisture or water
- Dimensions and placement of excavation conforms with plans
- Sediment and erosion control devices in place

3. Installation Phase (Only <u>after</u> all contributing drainage area has been stabilized)

- Proper placement of filter fabric (non-woven) below locations of underdrains
- Proper placement of underdrains and cleanouts (size, schedule, location)
- Proper Placement of gravel layer on top of underdrains
- Proper placement choking stone around gravel layer
- Proper placement of washed sand layer above choking stone layer.
- Backfill soil conforms with specifications and placed per details and specifications
- Proper grade establishment
- Silt fence installed around perimeter of BMP to keep sediment out of fill material
- Proper placement of plant materials (type, size, quantity, tags)
- Correct placement of mulch cover
- Install sod filter strip around perimeter

4. Final Inspection and As-Built

- Changes in grading, facility depth, size, soil medium, plant materials, etc., shall require an As-built Plan whether private or public to reflect the changes.
- Maintenance Agreement/Covenant for bioretention facilities located on private property
- All landscaping installed/landscape warrantee documentation received
- Bioretention configuration, size and depth are in accordance with approved plans
- Landscaping certification documentation for bioretention facility(ies)
- Drainage area conforms to approved plan
- Drainage area completely stabilized

Install sediment control devices as shown on the plans.
Construction time**: ½ Day**

2. Grade site to elevations shown on plan. If applicable, construct curb openings, and/or remove and replace existing concrete as specified on the plan. Curb openings shall be blocked or other measures taken to prohibit drainage from entering construction area. At the end of each workday, all excavations shall be protected by construction safety fencing or temporary backfill as needed.
Construction time**: 1 Day**

3. Stabilize grading within Limit of Disturbance except for Bioretention Area. Bioretention areas may be utilized as sediment traps if the proposed invert of the bioretention facility is 1 foot lower than the sediment trap and if approved on the plans.
Construction time**: ½ Day**

4. Excavate bioretention area to proposed invert depth and scarify the existing soil surfaces, taking care not to compact the in-situ materials.
Construction time**: ½ Day**

5. Install underdrain system, cleanout pipe and outlet device.
Construction time**: ½ Day**

6. Inspection required of underdrain and amended soil mix.

7. Cover underdrain with washed stone (#57). Install choking stone and washed sand layer. Install amended soil mix as specified in the plans and detailed in the specifications.
Construction time**: ½ Day**

8. Presoak the planting soil prior to planting vegetation to allow for settlement. This can be done by water truck or allowing water to enter the pit from a rain event.
Construction time**: ¼ Day**

9. Excavate or fill to achieve proper design grade, leaving space for the upper layer of mulch and/or topsoil that will bring the surface to final grade and ready for planting. Create sheet flow into bioretention area to avoid concentrated flow and erosion.
Construction time**: ¼ Day**

10. Plant vegetation specified in the planting plan for Bioretention Area and sod perimeter.
Construction time**: ½ Day**

11. Mulch and install erosion protection at entrance points. Remove sediment control practices or entrance blocks with inspector authorization.
Construction time**: ½ Day**

12. Final inspection required.

Total Estimated Construction Time = 5.0 Days

Figure 8.4. Sequence of Construction for Bioretention BMPs

Section 9. Plan Submittal/Review

9.1 Introduction

Plan submittal requirements will remain the same for all commercial and residential projects. Storm Water Management Permit Application plans demonstrating compliance with Section 3, Performance Criteria, are required for all projects, unless exempted under Applicability of the Huntersville Post-Construction Ordinance.

9.2 Site Evaluation Tool

The Site Evaluation Tool (SET) is a water quality model that assesses pre-development runoff and pollutant loading rates and provides a methodology for implementing LID best management practices (BMPs) into a development for achieving the established Performance Criteria (Section 3). The SET is not required to be submitted; however, the SET can be used to assist in design. The SET requires the following input describing pre- and post-construction conditions:

1. The size of the project.
2. For residential development, the number of homes within the project to be served by septic systems.
3. For commercial development using on-site wastewater disposal BMPs, the estimated waste volume in gallons/year.
4. The fraction of the project area that is distributed within each of the hydrologic soil groups A, B, C, or D.
5. The land areas (in square feet) shown on the detailed site plan for the proposed development as occupied by the following pervious areas:
   a. Forest/Wetland
   b. Meadow (open space maintained in a natural condition)
   c. Lawn
6. The areas (in square feet) of the project that will be covered by the following impervious areas:
   a. Rooftops (all buildings)
   b. Driveways and/or Parking Lots (including gravel surfaces)
   c. Roads
   d. Sidewalks
   e. Other Impervious Areas (e.g. tennis courts, patios)
7. The surface areas (in square feet) of all storm water management facilities or BMPs planned for the project including structural features (ponds, wetlands) and design features such as swales, channels and infiltration galleries).
8. The same division of land uses, impervious areas, and storm water management facilities as items 5-7 for the condition of the site prior to development. For most sites the existing land use will be a combination of forest/wetland and meadow.
9. A division of the project area into distinct drainage areas that are served by specific storm water management facilities and/or BMPs.
10. Additional inputs are required for some BMPs; ponds and wetlands require entry of detention storage, and stream buffers require average buffer width and the proportion of the drainage area within 150 feet + the buffer width of the stream. Also, pollutant removal efficiencies and

hydraulic properties must be specified on the site plan that are not included in the menu of BMP choices.
11. The average slope and the longest flow length for each drainage area.

A copy of the SET and detailed documentation can be obtained from the following sources:
- Via US Mail: Mecklenburg County Water Quality Program,
2145 Suttle Avenue
Charlotte, N.C. 28208-5237
Attn: Rusty Rozzelle
- Via Telephone: 980-314-3217
- Via the Internet: http://stormwater.charmeck.org (select "Regulations," select "Huntersville," select "Low Impact Development (LID)," select "Mecklenburg County Site Evaluation Tool")

9.3 Plan Submittal Requirements

Plan submittal procedures will remain as described in the Town of Huntersville Zoning Ordinance and the Mecklenburg County Land Use and Environmental Services Agency Plan (LUESA) Submittal Guidelines, with the following additions:

1. Concept Plan: A Concept Plan meeting is required with Town staff and the Mecklenburg County Water Quality Program (2145 Suttle Avenue, Charlotte, N.C. 28208-5237) prior to a formal plan submittal. The plan shall be on a topographical map showing original contours at intervals of not less than two feet and existing tree lines. It should show in sketch form the proposed layout of streets, lots, and other features in relation to existing conditions as well as how the layout minimizes the impact to steep slopes, natural drainage ways and wooded areas. This Low Impact Design shall include the following:
   - The boundary/property lines of the property being developed as well as the location of property lines that intersect the property being developed;
   - Water courses on the land to be subdivided or developed;
   - Impervious area calculations;
   - The location, names, and rights-of-way of any existing streets on or within 300 feet of the land to be subdivided or developed;
   - The location of all property lines which intersect the boundaries of the property being subdivided or developed;
   - Limits of all wooded areas (locate all trees 6-inches in diameter or larger for special or conditional uses);
   - Soils type (HSG) and limits;
   - Contour map at two (2) foot intervals extending 100 feet beyond the property boundary;
   - Slope Analysis showing (0% - 10%, 10% - 15%, 15% - 25%, >25%);
   - Natural drainage ways (woodland swales, concentrated flows), ponds;
   - Wetlands limits (copy of appropriate Federal and State permits/verification to be submitted with preliminary plans);
   - Rough finished grades, the location of proposed streets, lots, parks or other open spaces, building lines, street cross-sections, number and type of buildings, and the location of any building restriction flood lines;

- Zoning information for the proposed project site and adjacent properties;
- Proposed front, rear, and side yard dimensions for each building type along each street type;
- The location and width of required S.W.I.M. buffers;
- Proposed LID BMPs and locations along with hydrologic analysis;
- The location and width of any S.W.I.M. stream buffers;
- The location of general buffers or screens required for the project area, as a whole;
- The scale of the plan, which shall not be smaller than 100 feet to the inch (All plans and details for BMPs must be drawn to scale for clarity and to aid in construction. Drawings not to scale often lead to construction problems and field errors, or simply cannot be built. Standard NCDOT details do not require a specific scale.)
- North point; date; and
- A small scale vicinity map.

2. Preliminary Plan: Preliminary Plans shall include the above listed information in addition to the Preliminary Plan submittal requirements outlined in the Huntersville Zoning Ordinance and the Mecklenburg County Land Use and Environmental Services Agency Plan Submittal Guidelines.

3. Storm Water Management Permit: A Storm Water Management Permit must be obtained by submitting an application demonstrating compliance with the Performance Criteria (see Section 3) and containing the following information:
   - BMP summary table, which lists all BMPs on the site and corresponding NAD 83 (feet) coordinates;
   - Calculations and design drawings with detailed BMP plans at 1 inch = 2 feet with 1-foot contours and spot elevations for each BMP and overall site hydrology calculations (see Section 5) illustrating compliance with Section 3, Performance Criteria. All special details shall be drawn to a specified scale for clarity.
   - Planting plan/schedule for each BMP illustrating plant location, species, and quantities; and
   - A Maintenance Covenant and Plan for all BMPs. This plan shall include the responsible party for each BMP and a schedule of routine maintenance activities to ensure proper performance. Prior to the approval of the Preliminary Plan and Storm Water Permit, an approved signed copy of the Maintenance Covenant and Plan that has been stamped by the Register of Deeds Office must be submitted to LUESA.

Upon approval of the Storm Water Management Permit, a record plat is required on all BMP structures and where improvements are not complete, a means of financial security must be posted as required by the Huntersville Post-Construction Ordinance. Upon completion of BMP structures and prior to the release of the financial security, a Maintenance Bond shall be required for a period of two years.

4. Plat Submittal: In addition to typical Final Plat requirements in the Huntersville Zoning Ordinance and the Mecklenburg County Land Use and Environmental Services Agency Plan Submittal Guidelines, the following additional requirements shall apply:

- All BMPs shall be named and recorded on the final plat and applicable deeds, with their corresponding NAD 83 (feet) coordinates. The following naming convention should be used for all BMPs: "Project or subdivision name – BMP Type – Number." For example, "Birkdale Phase V – Bioretention Garden – 1".
- Any vegetation, tree save areas, open space or site conditions that contribute to the project's compliance with Section 3, Performance Criteria, shall be called out, protected, and recorded through the plat and applicable deeds.
- Show all storm drainage easements leading to the BMP.
- Show a 12-foot wide stable maintenance access route. The access route must be contained within a 20-foot wide maintenance access easement from the BMP facility to a public right-of-way.
- Dimensions of BMP easement area with the corresponding BMP identification name/number should be illustrated on the plat.
- Show storm drainage easements around BMP or leading to BMP including access easement.
- Show the maximum impervious for watershed protection areas.
- The following statements must be including on the plat:

  "The purpose of the BMP is to treat/reduce the pollutants associated with storm water runoff in order to minimize negative effects to downstream receiving waters. The easement around the BMP is to allow storm water conveyance and system maintenance. Any buildings and/or obstructions which impede storm water flow or maintenance are prohibited."

  "This plat contains water quality features that must be maintained in accordance with the recorded Maintenance Covenant as specified in Section 8.17.13(a) of the Huntersville Zoning Ordinance. Removal of plants or disturbance of the BMP structure or otherwise affecting the overall functionality of the BMP for reasons other than maintenance is prohibited."

  Prior to approval of the plat, an approved, signed copy of the Maintenance Covenant and Plan that has been stamped by the Register of Deeds Office must be submitted to LUESA.

5. As-Built Surveys: As-Built BMP surveys are required for all BMPs. As-built surveys must be approved prior to issuing an occupancy permit or releasing a performance bond.

Occupancy Permit: Prior to the issuance of an Occupancy Permit for any building within a permitted development served by a BMP, the applicant or owner of the BMP shall establish a formal Maintenance Covenant, approved by the Mecklenburg County Land Use and Environmental Services Agency, and recorded in the Office of the Register of Deeds in which the owner acknowledges the duty of the owner and all subsequent owners of the property to maintain the BMP in accordance with the terms of the Covenant. This Maintenance Covenant is required for all BMPs constructed on privately-owned property and not within a public easement. The Administrative Manual for implementation of the Post-Construction Storm Water Ordinance contains an example of a typical Maintenance Covenant. This Manual is available on the following website: http://stormwater.charmeck.org (select "Regulations", select "Post-Construction Programs & Manuals", select "Mecklenburg County, Towns of Cornelius, Davidson, Matthews, Mint Hill, Huntersville & Pineville", select "Post-Construction Administrative Manual – County and Towns"). See Section 8.3.2 of this manual for additional information on maintenance responsibilities.

9.4 Bonding

In extenuating circumstances when BMP construction cannot reasonably be completed before the building is ready for occupancy, a performance bond shall be required. The bond shall be for a time period deemed appropriate by the inspector, not exceeding one year from the time of full occupancy or three years for phased development. Once the bond and bond agreement have been accepted by the County, the Water Quality Hold on the building permit can be released.

9.4.1 Posting Performance Bonds

A bond must be posted for the BMPs on each plat. The purpose of the bond is to ensure that in the absence of required completed work, a means of financial security is posted to ensure the completion of work. Bonds provide the County with financial resources to complete required public improvements in the event of developer/builder default. Bonds will be considered in default and will be called by Mecklenburg County if BMPs are not constructed within 3 years from the construction bond date or if the drainage area is ≥75% built out. A bond estimate should include complete construction, materials and installation costs for each BMP. Estimates will only be accepted by the design engineer or by a contractor in the form of a Certified Contractor Bid in detailed line item format. Estimates without adequate detail will not be accepted. The bond amount will be 120% of the certified bid + $10,000. If Mecklenburg County estimates the bond amount, the following formula will be used: (Surface Area of Structure x $17.00 / square foot + $15,000). The bond amount will also include contingencies and legal fees and are subject to change. Bonding for the BMP may be posted in a common bond with other required subdivision or zoning improvements or may be posted separately.

The developer may choose from the following options regarding bonds:

- Surety Bond – Issued through a surety company (similar to an insurance policy).
- Letter of Credit – Issued through a credited bank with Mecklenburg County or a full service bank within Mecklenburg County.
- Cash Bond – A certified check to Mecklenburg County or a Company Check to Mecklenburg County.

Blank bond forms are available on the following website: http://stormwater.charmeck.org (select "Regulations," select "Post-Construction SW Management Permits Forms (County and Six Towns Only)….," select "Forms," select "BMP Installation Bond Application Forms").

9.4.2 Bond Reduction / Release

A one-time bond reduction is permitted on performance bonds when at least 50% of the construction has been completed and upon approval from the inspector. Bonds are administered at the LUESA Office and reduction requests should be made to this office.

9.4.3 Maintenance Bonds

BMP Maintenance or Warranty Bonds are required for all structural BMPs. Blank bond forms are available on the following website: http://stormwater.charmeck.org (select "Regulations," select "Post-Construction SW Management Permits Forms (County and Six Towns Only) ….," select "Forms," select "BMP Maintenance Bond Application Forms"). The purpose of these bonds is to ensure that funds are secured to maintain BMPs if the owner should fail to do so in which case Mecklenburg County would cash the bond to obtain the money to perform the necessary maintenance. The value of the bond shall be: 30% of BMP construction or $5.10 Square Foot of surface area plus a $10,000 base bond amount. The bonds shall be posted by the owner for a period of not less than two (2) years from the final approval of the BMP by the Storm Water Administrator. The owner is responsible for all repairs and/or material replacement required to ensure the operation of the BMP in accordance with approved plans and specifications. After the two (2) year warranty period, the owner may request that the Storm Water Administrator release the bond. Before the bond is released, the Water Quality inspector shall conduct a field evaluation of the BMP to ensure proper operation and maintenance. If this field evaluation reveals that the BMP is not being maintained, the inspector may choose to extend the maintenance bond for an additional year. If it is confirmed that the BMP is being properly maintained, the inspector shall complete a Bond Release Form. This form shall be provided to the bond reviewer and the bond shall be released.

9.4.4 Bonds for Public Entities

Public entities are not required to obtain sureties for either the installation or maintenance of water quality BMPs provided a letter signed by the manager or director of the project provides suitable assurances that the necessary improvements will be installed and maintained in accordance with Ordinance requirements. Public entities shall include but not be limited to Charlotte-Mecklenburg Schools, City of Charlotte, Charlotte-Mecklenburg Utilities, Charlotte-Mecklenburg Storm Water Services, Mecklenburg County and all the Towns as well as the State and Federal government. The letter of assurance shall be addressed to the Storm Water Administrator and upon his approval the surety requirement will be waived and all holds/ approvals for the project released.

Section 10. Inspection and Enforcement

10.1 Introduction

This Section establishes inspection and enforcement guidelines to be followed for this manual and corresponding Ordinance. The guidelines are to be applied uniformly for inspection of private and public water quality measures.

10.2 Authority

The provisions of the Huntersville Post-Construction Ordinance shall be enforced by the Mecklenburg County Land Use and Environmental Services Agency (LUESA). LUESA staff shall be authorized by the Huntersville Town Manager to perform the following functions:

1. Conduct inspections and file reports as necessary during construction of water quality BMPs to ensure compliance with the approved plans and permits.
2. Furnish the permitting agent or owner of the property the results of the inspection in a timely manner (See Section 10.6).
3. Issue a Field Inspection Report (FIR) to the permitting agent or owner when any portion of the work does not comply with the approved plans and/or permits (see Section 10.6.1).
4. Issue a Notice of Violation in accordance with these guidelines as the result of unsatisfactory work or progress, failure to comply with approved plans and permits, and any non-compliance of the requirements of the Huntersville Post-Construction Ordinance.
5. Issue a Stop Work Order or Revocation of Permit as the result of unsafe conditions, working without a permit, unsatisfactory work or progress, or other non-compliance.
6. Issue Civil Citations(s), Civil Actions(s), or Criminal Action(s) listed in Section 10.7 due to unsafe conditions, non-compliance with a Stop Work Order, unsatisfactory work or progress, or other non-compliance (see appropriate Section of the Huntersville Zoning Ordinance).
7. Perform a final inspection upon the completion of water quality structures to determine if the completed work is constructed in accordance with the approved Storm Water Management Plan and associated plans/documents.

10.3 Inspection Responsibilities

Both LUESA staff and property owners shall be responsible for performing all inspection activities described in this Section under authorization of the Huntersville Town Manager.

10.4 Inspection Requirements During Construction

Inspections will be conducted by LUESA staff at the request of the owner/developer and at specified stages of construction for each water quality BMP and/or technique described below. Final inspections/approvals are required for all BMPs, but additional inspections/ approvals are required during the construction phase of Drywell/Infiltration Trenches and Bioretention BMPs, as specified in Section 10.4.1 and 10.4.2. The inspectors will also make unscheduled inspections to ensure compliance with the requirements of this manual and corresponding Ordinance as they deem necessary. The inspector will be authorized to accept minor field changes proposed by the owner/contractor. Inspections shall be requested at least 24 hours in advance. When requesting an inspection, the permit number, type of inspection, contact name and phone number must be provided.

10.4.1 Drywell or Infiltration Trench

The following inspections are required to be conducted by LUESA staff for construction of a Drywell or Infiltration Trench. The inspector may require additional inspections.

1. Excavation Inspection - An inspection must be conducted after excavation and immediately prior to the final topsoil installation. During this inspection, the inspector shall verify the following:
   a. Trench dimensions comply with approved plans.
   b. Adequate sediment control protection has been installed.
   c. Approved filter fabric has been cut and installed to cover the trench beneath the underdrain(s). A six-inch minimum overlap is required between strips of cloth. Extruding tree roots or other obstacles must be removed from the trench base to prevent the fabric from tearing.
   d. Observation well or inlet has be installed as specified on plans prior to stone placement. Perforations shall not extend beyond gravel trench.
   e. Installation of 1 1/2 inch to 3 inch washed stone. Care must be used when dumping the stone to ensure the filter cloth does not tear.
   f. Installation of the inlet pipe for Drywells.
   g. Placement of topsoil on-site (but not installed).

2. Final Inspection - During this inspection, the inspector will verify the following:
   a. Gravel surface must be completely covered with cloth and backfilled with topsoil for Drywells and Infiltration Trenches. For Dry wells. surface inlets must be installed as per approved plans and the observation well must be capped.

Upon stabilization of the area, if the above items have been completed satisfactorily, a final inspection report will be issued and approved by the inspector. The final inspection is required before requesting a Final Certificate of Occupancy.

10.4.2 Bioretention BMPs

The following inspections are required for construction of a bioretention BMP. The inspector may require additional inspections.

1. Excavation and Underdrain Inspection - An inspection shall be conducted after excavation and underdrain installation and immediately prior to the final stone and topsoil installation. During this inspection, the inspector shall verify the following:
   a. Trench dimensions comply with approved plans.
   b. Adequate sediment control protection has been installed.
   c. Stone, underdrain choking stone, and sand layer have been installed as per the approved plan.
   d. Proper grade has been establishment.

   e. Placement of topsoil on-site (but not installed).

2. Final Inspection - During this inspection, the inspector shall verify the following:
   a. Proper topsoil installation.
   b. Proper plant installation (native plants, size) and plant health as per the approved plan.
   c. Maintenance agreement/covenant complete.
   d. Outlet properly installed.
   e. Proper placement of ground cover/mulch.
   f. Drainage area completely stabilized.
   g. Drainage area conforms to approved plan.

Upon stabilization of the area, if the above items have been completed satisfactorily, a final inspection report will be issued and approved by the inspector. The final inspection is required before requesting a Final Certificate of Occupancy.

10.5 Maintenance Inspections

10.5.1 Introduction

Maintenance inspections must be performed by the owner at a minimum of once a year to ensure that water quality BMPs remain functional and properly maintained. These inspections must be conducted by a qualified registered North Carolina professional engineer or landscape architect performing services only in their area of competence. Written inspections reports must be provided to the Mecklenburg County Land Development at 2145 Suttle Avenue, Charlotte, N.C. 28208-5237. Inspection reports will be maintained on file at this office.

Additionally, LUESA staff will perform maintenance inspections once every three (3) years.

10.5.2 Responsibilities and Procedures

The owner of the property will be contacted LUESA staff prior to a maintenance inspection. If the owner cannot be contacted, the inspection will be performed and a report will be sent to the owner.

1. A Warning Citation and/or Notice of Violation will be issued for any maintenance and/or repairs required.
2. The owner shall begin to make corrections to the violations within 10 days of the date of the Warning Citation and/or Notice of Violation. After 10 days, Civil Citations may be issued as governed in Section 10.7.2.3.
3. If an imminent hazard exists, the inspector may post the Water Quality BMP unsafe as per the North Carolina State Building Code and require immediate repair.
4. Upon the owner’s failure to comply with the Warning Citation, Notice of Violation, Civil Citation(s), the inspector may issue a Civil or Criminal Action against the property owner and/or contractor.

10.6 Approvals and Reports

Approvals and inspection reports shall be maintained by the inspector to insure proper notification of construction approvals and failure to comply with the approved plans to the owner, contractor or developer.

10.6.1 Field Inspection Report

The purpose of the Field Inspection Report (FIR) is to notify the owner and or contractor/developer of construction deficiencies noted by the inspector, and to direct repairs and corrections.

FIRs will be issued when the permittee or agent is directed to make changes to their work to satisfy this manual and corresponding Ordinance, approved storm water design plans, or specifications. The notice shall set forth the nature of the corrections required and the time allotted to make the necessary corrections. FIRs shall be issued when the following has occurred:

1. Failure to comply with the design plan. Incorrect measurements, using improper materials or failing to follow proper procedures can prompt the issuance of a FIR. FIRs shall be issued in writing except when a verbal notice would result in immediate compliance as the work is being completed. Verbal notices shall be noted in the project file.
2. Failure to provide certification for water quality structures. The inspector shall issue a FIR to the owner/developer requesting certifications and/or as-builts. A compliance date and a mailing address for sending needed information shall be supplied.

10.7 Administration and Enforcement

If an application for a Building Permit, Grading Permit, Storm Water Permit, Zoning Land Use Permit or Certificate of Occupancy is denied because of non-compliance with the Huntersville Post-Construction Ordinance, the inspector shall provide notification of the denial and of the reasons therefore.

If the owner fails to comply with the FIR during construction, the inspector shall provide notification of the denial and of the reasons therefore.

10.7.1 Right to Appeal

If a request for a permit is disapproved or if a ruling of the Zoning Administrator is questioned, any aggrieved party may appeal such ruling to the Huntersville Board of Adjustment as provided in Section 10.3 of the Huntersville Zoning Ordinance. An appeal or variance to the Board of Adjustment, lawfully and completely filed **within 30 days of the date of the decision**, shall stay enforcement action and penalties until a hearing has been held and a decision rendered by the Board of Adjustment.

10.7.2 Penalties

In case any water quality BMP is installed, constructed, reconstructed, altered, repaired, converted or maintained in violation of these regulations, an action for injunction, mandamus, or other appropriate action or proceeding to prevent such violation may be instituted by the Zoning Administrator or other authority designated by the Board of Commissioners as enforcement agent(s) for the Huntersville Post-Construction Ordinance. Penalties and remedies are stated in Section 10.2.3 of the Huntersville Zoning Ordinance and as listed below:

1. Notice of Violation. The inspector will issue a Notice of Violation to the owner upon non-compliance of the Huntersville Post-Construction Ordinance. In most cases a FIR will be used for the first offense. Subsequent noncompliance with these regulations or failure to complete the items on the FIR within the specified period of time will result in Notice of Violation.

2. Stop Work Order Issuance and Revocation of Permits. Whenever a water quality BMP or part thereof is being installed, constructed, renovated, altered, or repaired in violation of any provisions of the Huntersville Post-Construction Ordinance, the inspector may order the specific part of the work that is in violation, or would be when the work is completed, to be immediately stopped. The Stop Work Order shall be in writing, directed to the person doing the work and/or owner, and shall state the specific work to be stopped, the specific reasons for cessation and the action(s) necessary to lawfully resume work.

   The Zoning Administrator may revoke any permit (e.g. building, grading, storm water, zoning use, certificate of occupancy) by written notification to the permit holder and/or owner when violations of this manual or corresponding Ordinance have occurred. Permits may be revoked when false statements or misrepresentations were made in securing the permit, work is being or has been done in substantial departure from the approved application or plan, there has been a failure to comply with the requirements of this manual or corresponding Ordinance, or a permit has been mistakenly issued in violation of this manual or corresponding Ordinance.

   Failure to comply with the proper construction sequence as outlined in the Huntersville Post-Construction Ordinance may cause a Notice of Violations/ Stop Work Orders to be issued in such cases as described below:

   a. Failure to notify the Department before beginning any work to implement the water quality BMP (including not requesting a pre-construction meeting):
      Any work that has been placed without a required inspection approval shall be certified in writing by a registered professional engineer before the next phase of construction begins. The inspector reserves the right to require investigative materials testing on all un-inspected facilities or devices at the sole expense of the permittee/owner. Any deficiencies that need to be corrected for work already started shall be listed and given a compliance date. The permittee shall be notified to call for future inspections as required, as well as any additional inspections required by the inspector.
   b. Failure to have work inspected and approved before continuing work:
      It is required that inspection point(s) not approved be certified in writing by a registered professional engineer. The inspector reserves the right to require investigative or materials testing on all un-inspected facilities or devices at the sole expense of the permittee/owner.
   c. Failure to call for a final inspection:

The inspector shall list all deficiencies that need to be corrected, give a compliance date, and request a letter of certification and/or as-builts (if required) be submitted. The owner or contractor/developer shall request a re-inspection after completing the corrections so another final inspection can be made.

d. Failure to provide certification for completed water quality BMPs:
If an engineer's certification and/or as-built is not received by the compliance date as required by a previously issued FIR, a Notice of Violation to the owner and/or developer shall be sent requesting certification and/or as-builts.

3. Civil Penalty. Pursuant to NC General Statute 160A-175, the regulations and standards of the manual or corresponding Ordinance may be enforced through the issuance of civil penalties by the Zoning Administrator for the following situations:

a. When a FIR, Notice of Violation and/or Stop Work Order has not been complied with or there has not been substantial progress in complying with the Notice of Violation and/or Stop Work Order.
b. On abandoned sites where no work has been on going, and continued non-compliance with a Notice of Violation may result in the issuance of repeated citations.
c. When a Stop Work Order is in effect and work continues in defiance of the order.
d. When repeated recurring violations of the same section of this manual or corresponding Ordinance. Each day that a violation remains uncorrected constitutes a separate violation of applicable code or ordinance.

Subsequent citations for the same violation may be issued by the Zoning Administrator if the offender does not pay the citation (except as otherwise provided in a warning situation) after it has been issued unless the offender has sought an Appeal to the Decision of the Zoning Administrator through the Board of Adjustment. Once the ten-day warning period has expired, each day which the violation continues shall subject the violator to additional citations to be issued by the Zoning Administrator.

The following penalties are hereby established:

a. Warning Citation and/or Notice of Violation - Correct Violation within 10 days.
b. First Citation - $50.
c. Second Citation for Same Offense - up to $200.
d. Third and Subsequent Citations for Same Offense - up to $500, then $500 per day.

A citation may be issued every day the violation continues after the 10 day warning period. Hazardous violations or violations that cause risk to the public's health or welfare may be fined immediately. If the offender fails to pay the civil penalties within 10 days after having been cited, the Town of Huntersville may recover the penalties in a civil action in the nature of debt.

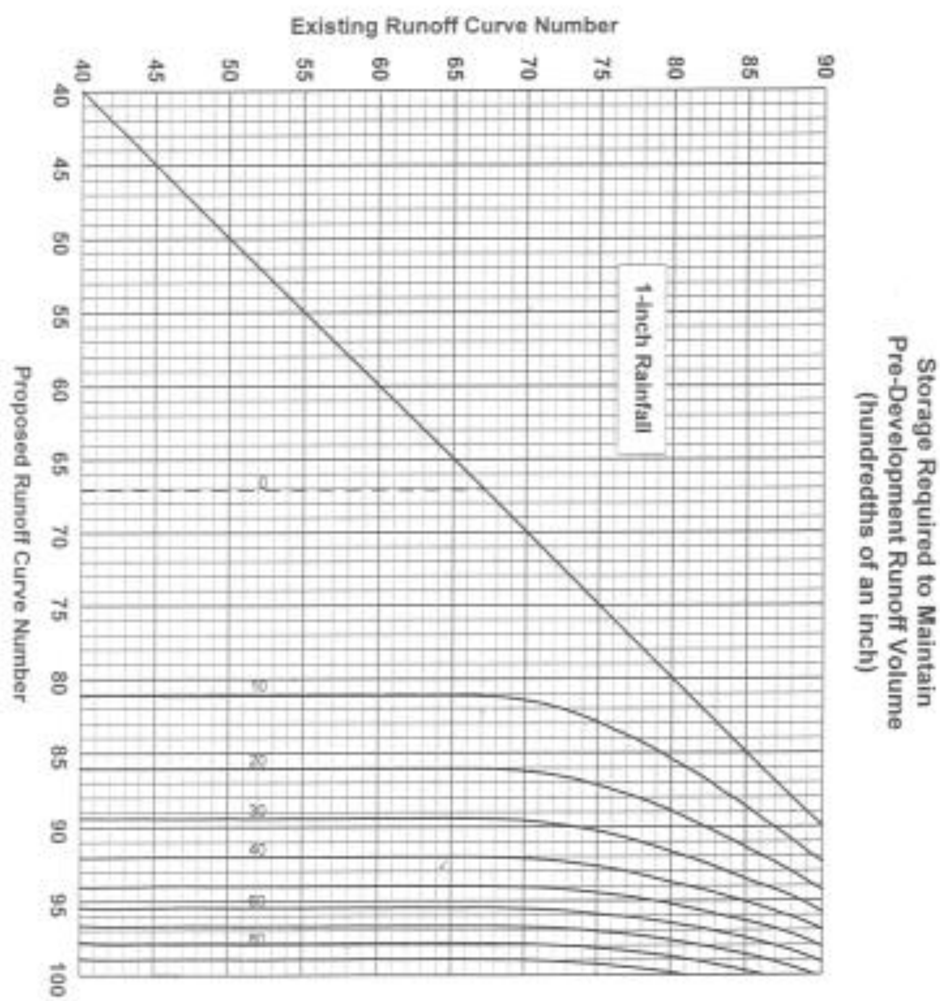
Appendix A: Huntersville Post-Construction Ordinance

Huntersville Zoning Ordinance
Section 8.17

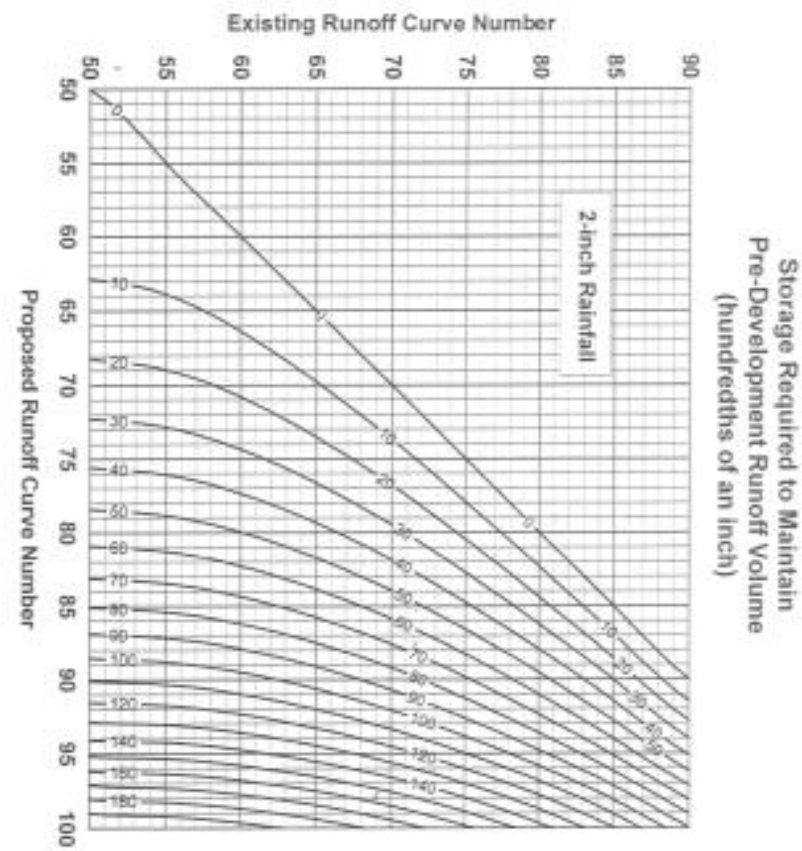
The ordinance is available on Huntersville's website by selecting "Departments," "Planning," "Interactive Zoning Ordinance," "Article 8," and "Article 8.17 – Water Quality." The link below will access the ordinance on Huntersville's website.

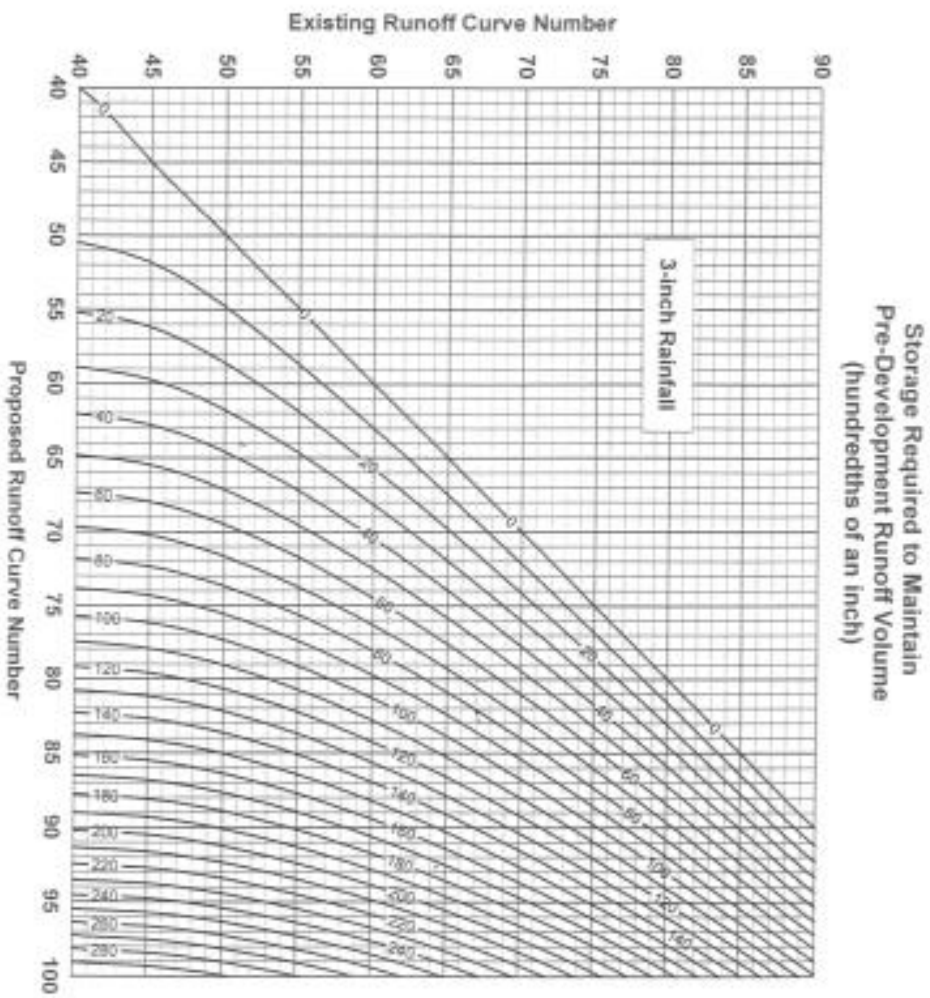
http://www.huntersville.org/Departments/Planning/OrdinancesandManuals/ZoningOrdinance/ARTICLE8GeneralProvisions.aspx#8.17

Appendix B: Storage Volume Required to Maintain the Pre-Development Runoff Volume Using Retention Storage


Storage Required to Maintain
Pre-Development Runoff Volume
(hundredths of an inch)
1-inch Rainfall
Existing Runoff Curve Number
40
45
50
55
60
65
70
75
80
85
90
Proposed Runoff Curve Number
40
45
50
55
60
65
70
75
80
85
90
95
100
10
20
30
40

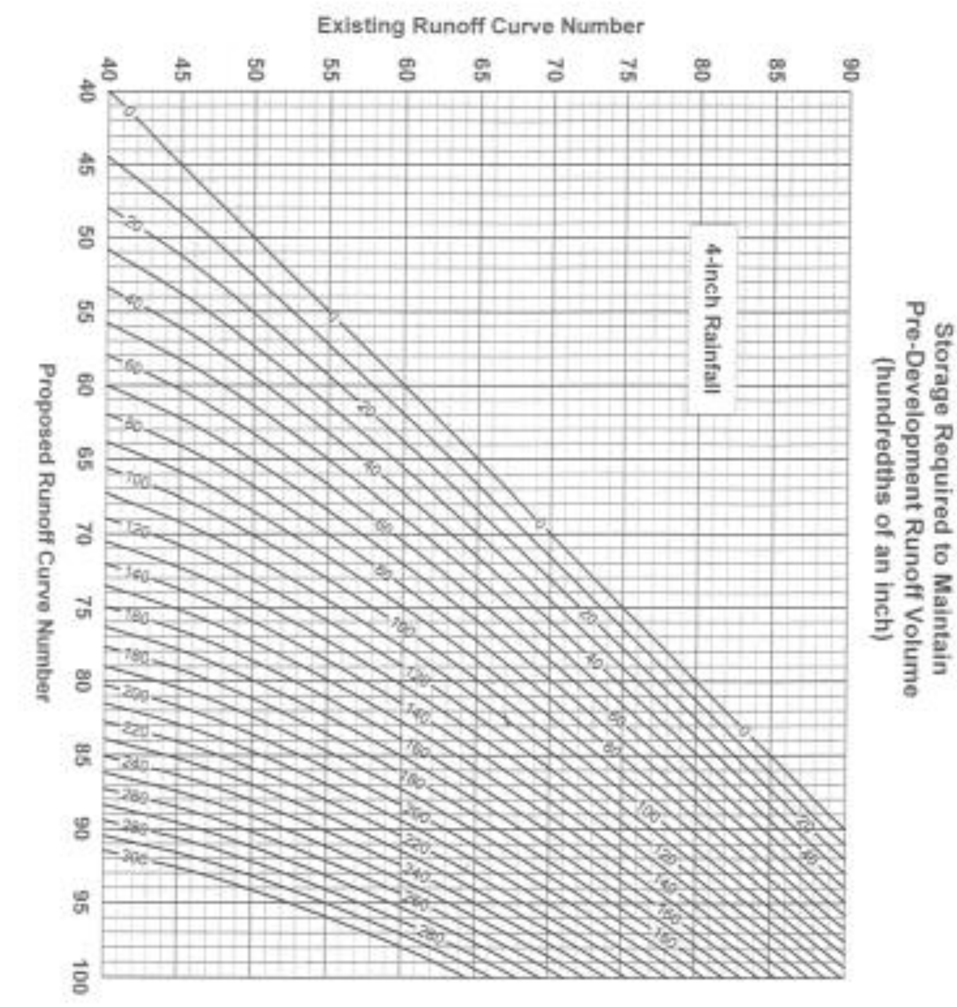
1


Existing Runoff Curve Number
Storage Required to Maintain
Pre-Development Runoff Volume
(hundredths of an inch)
2-inch Rainfall
Proposed Runoff Curve Number

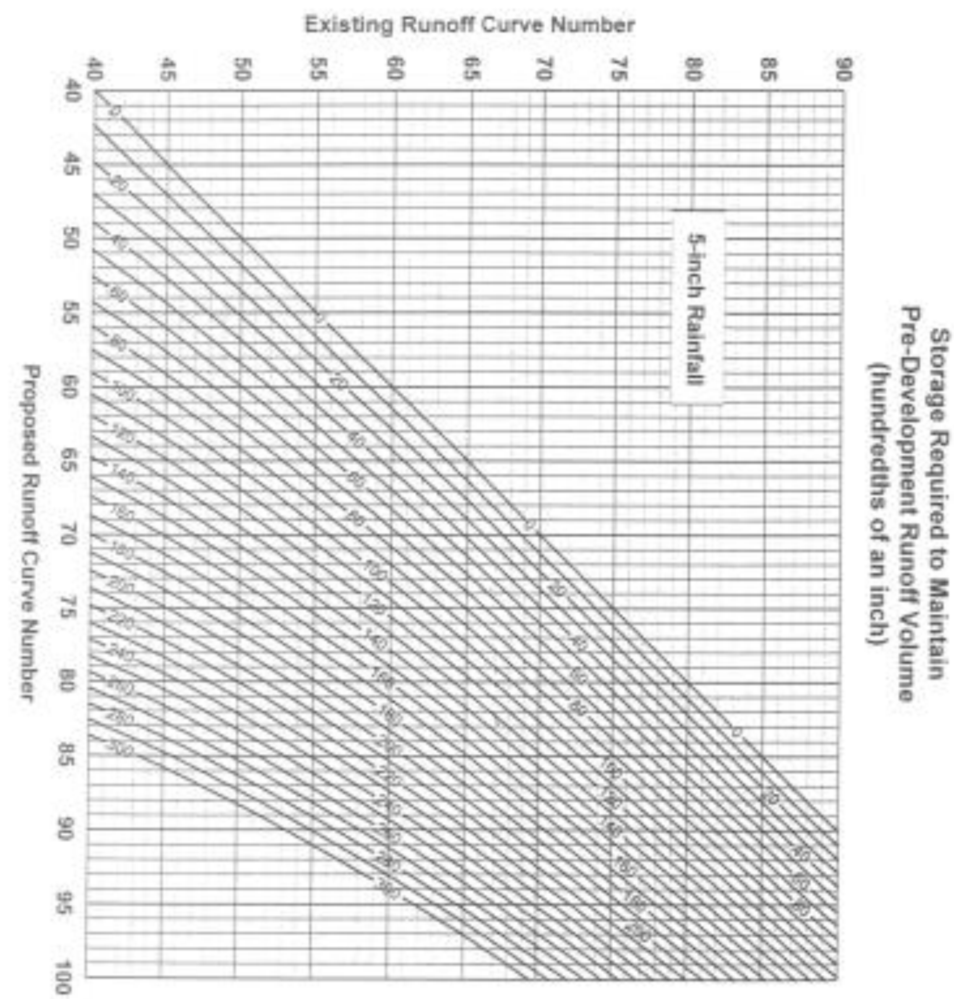


Existing Runoff Curve Number
Storage Required to Maintain
Pre-Development Runoff Volume
(hundredths of an inch)
3-inch Rainfall
Proposed Runoff Curve Number

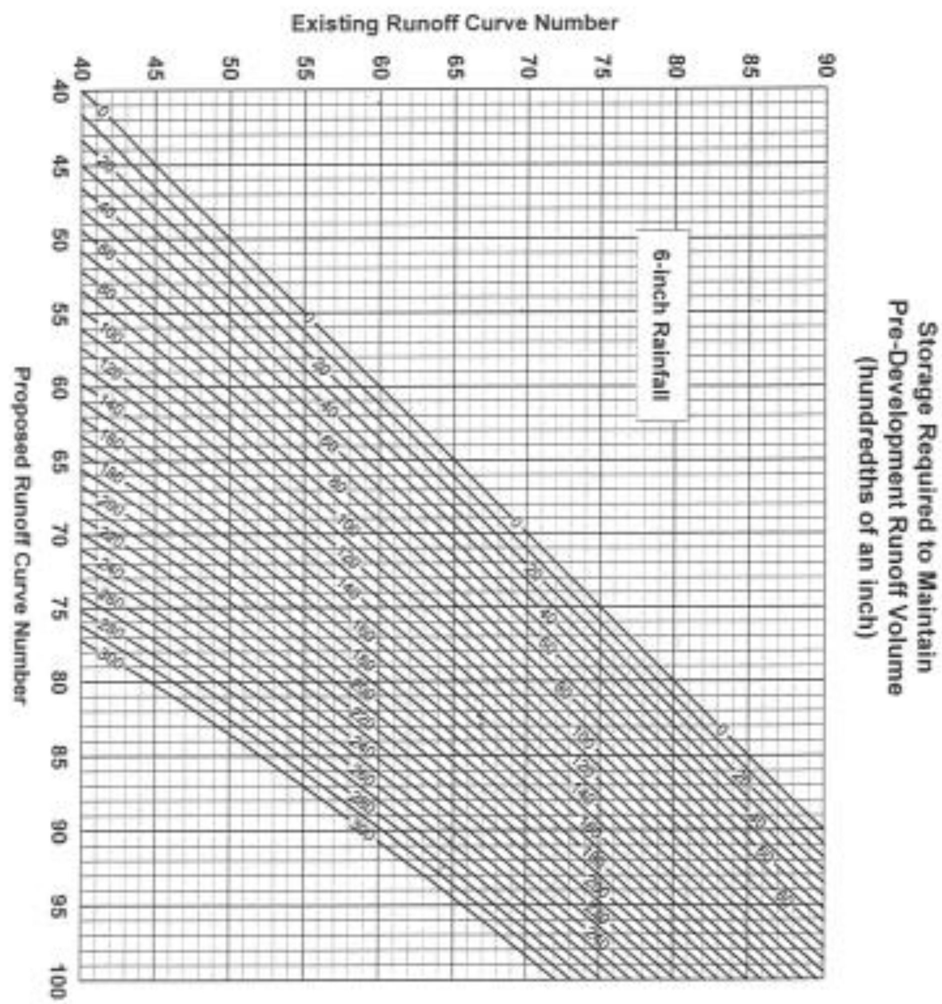
3

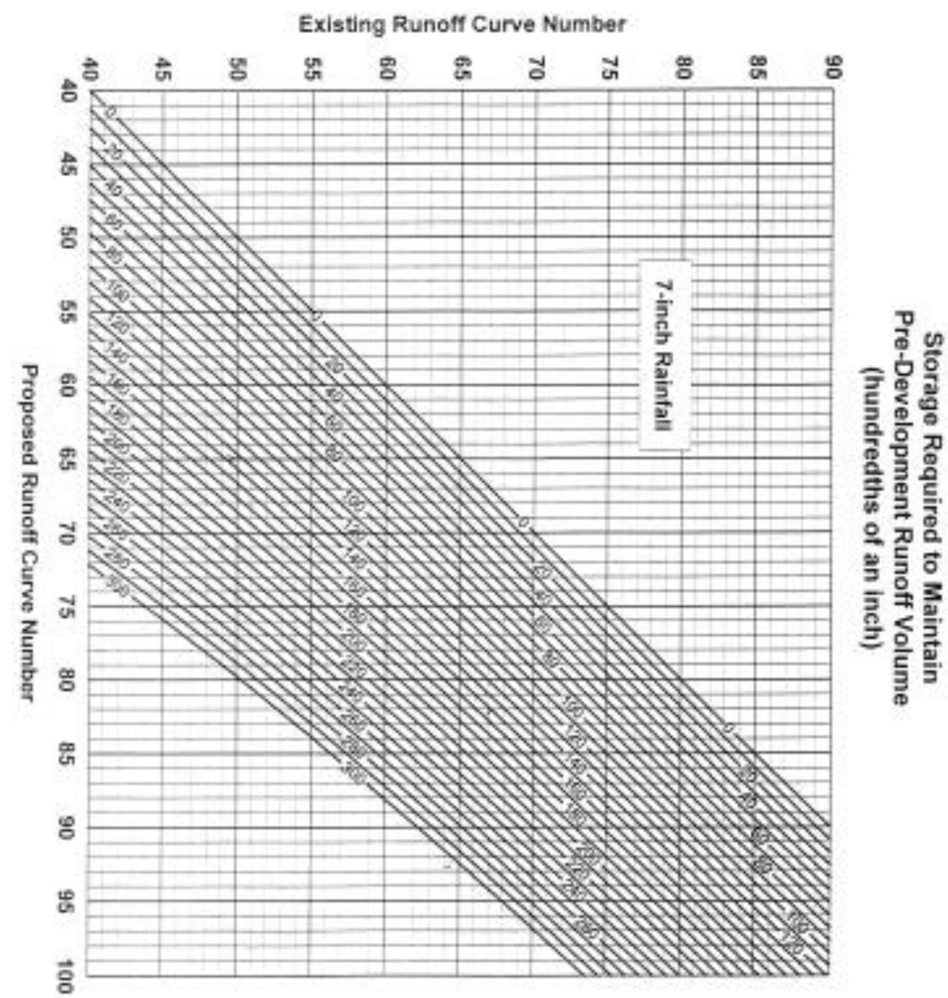

Existing Runoff Curve Number
Storage Required to Maintain
Pre-Development Runoff Volume
(hundredths of an inch)
4-inch Rainfall
Proposed Runoff Curve Number
40
45
50
55
60
65
70
75
80
85
90
95
100

4

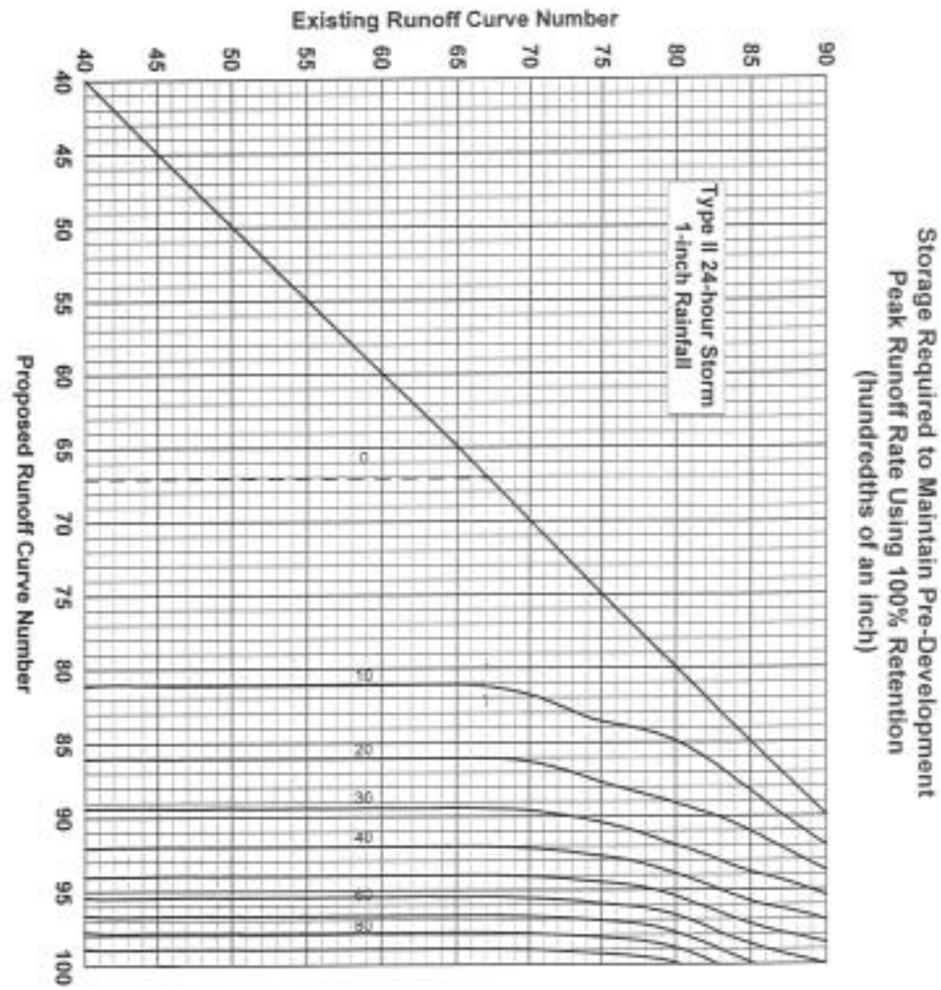

Storage Required to Maintain
Pre-Development Runoff Volume
(hundredths of an inch)
5-inch Rainfall
Existing Runoff Curve Number
Proposed Runoff Curve Number

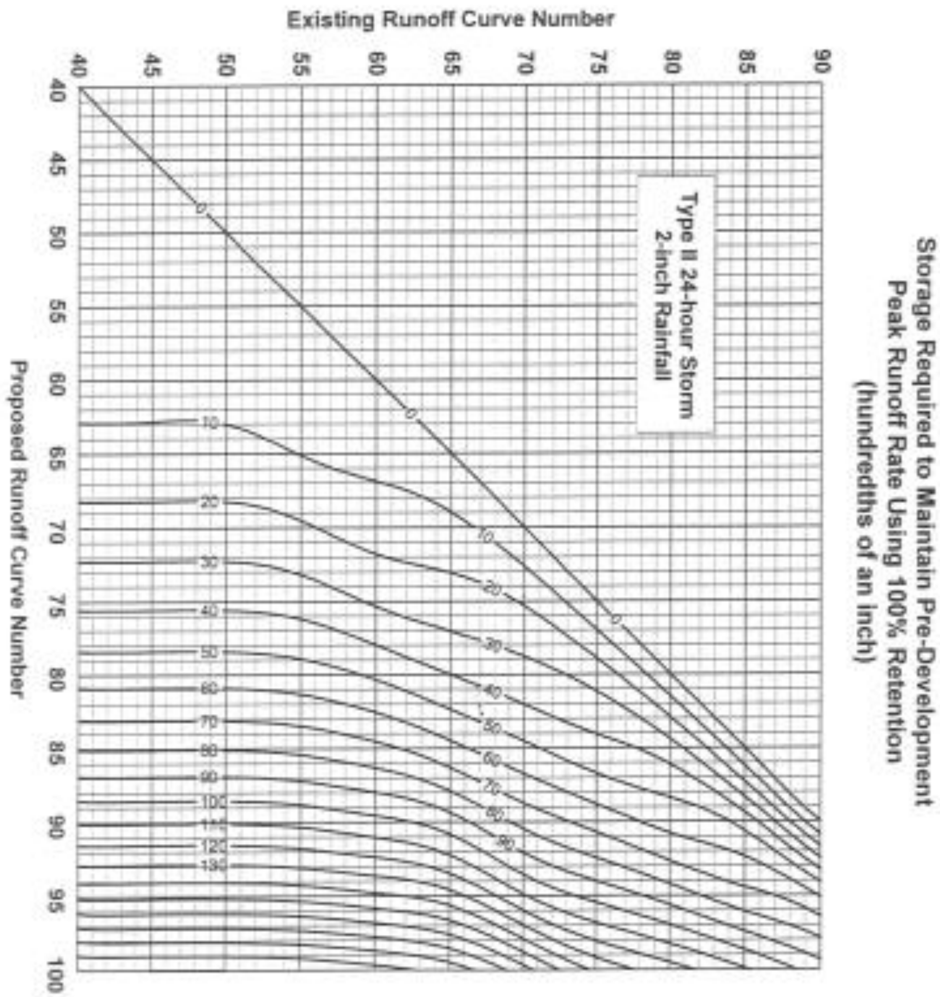
5

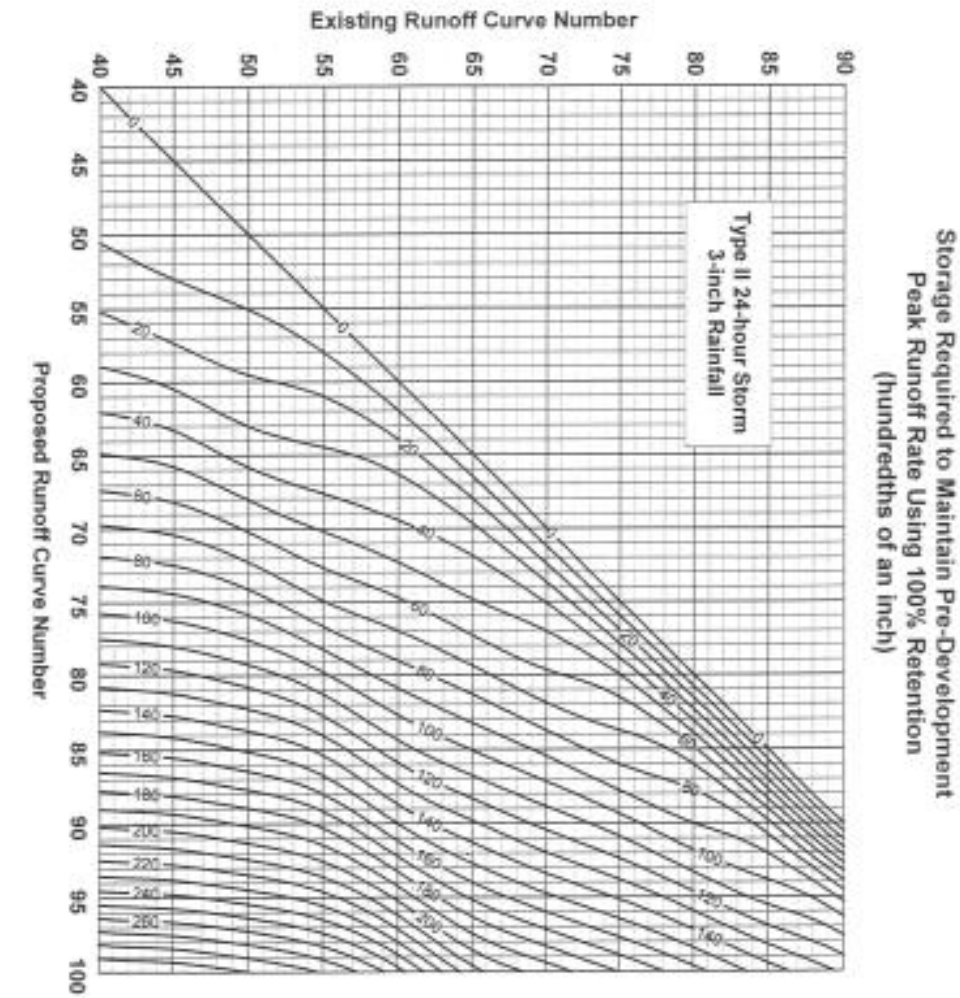

Storage Required to Maintain
Pre-Development Runoff Volume
(hundredths of an inch)
6-inch Rainfall
Existing Runoff Curve Number
Proposed Runoff Curve Number


Storage Required to Maintain
Pre-Development Runoff Volume
(hundredths of an inch)
7-inch Rainfall
Existing Runoff Curve Number
Proposed Runoff Curve Number
40
45
50
55
60
65
70
75
80
85
90
95
100

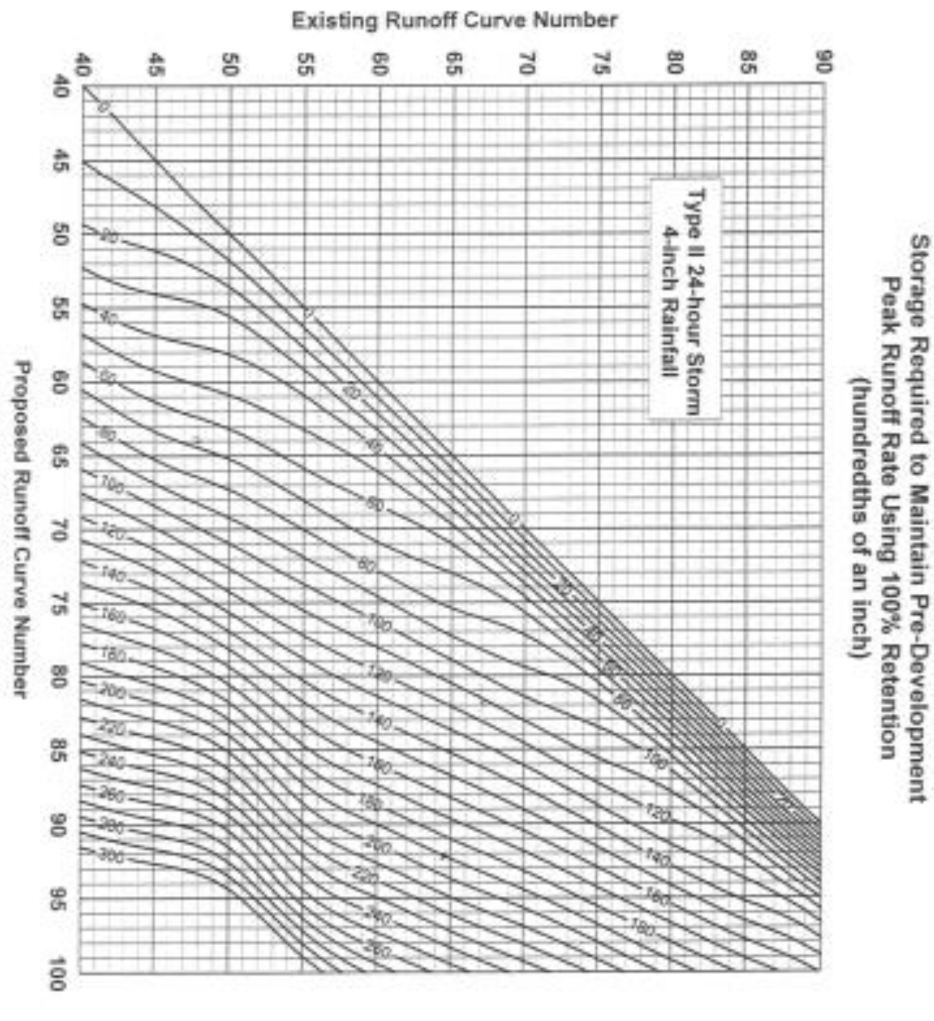
Appendix C: Storage Volume Required to Maintain the Pre-Development Peak Runoff Rate Using 100% Retention Storage - Type 2 24-Hour Storage Chart Series

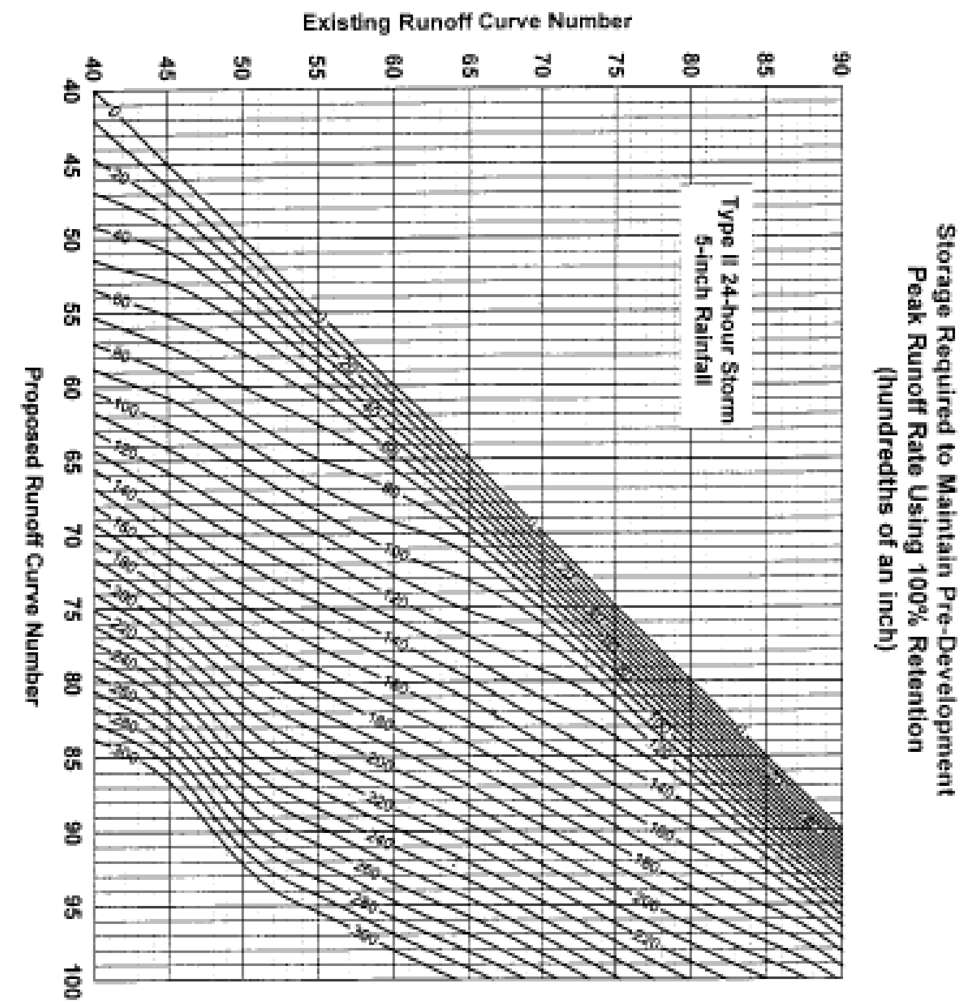

Storage Required to Maintain Pre-Development
Peak Runoff Rate Using 100% Retention
(hundredths of an inch)
Existing Runoff Curve Number
Proposed Runoff Curve Number
Type II 24-hour Storm
1-inch Rainfall
40
45
50
55
60
65
70
75
80
85
90
95
100
0
10
20
30
40
60
80

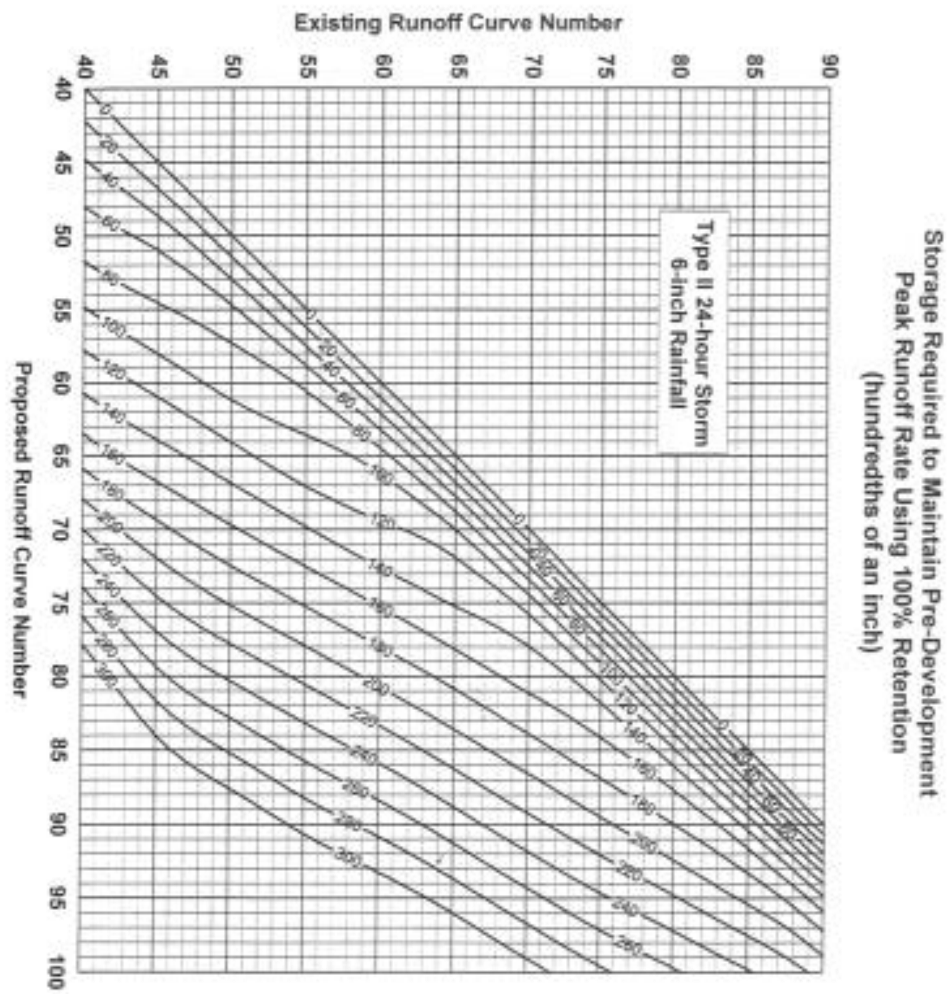

Storage Required to Maintain Pre-Development
Peak Runoff Rate Using 100% Retention
(hundredths of an inch)
Type II 24-hour Storm
2-inch Rainfall
Existing Runoff Curve Number
Proposed Runoff Curve Number

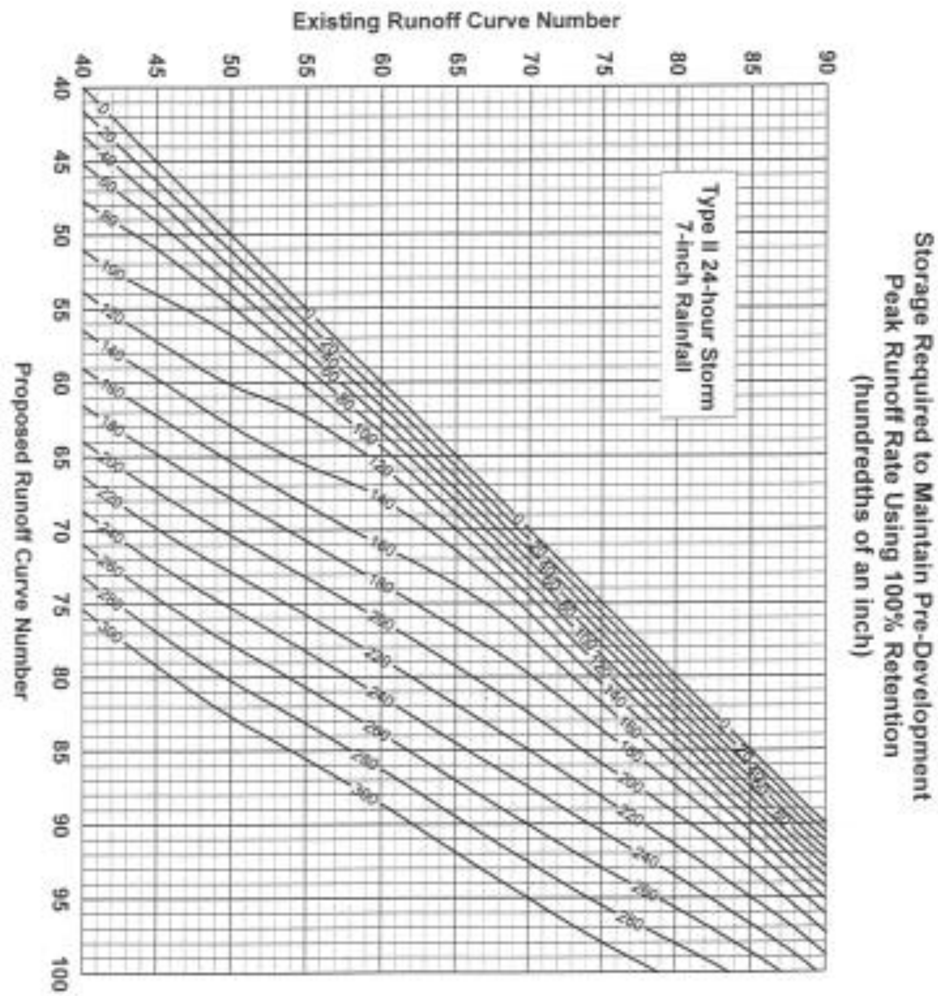


Storage Required to Maintain Pre-Development
Peak Runoff Rate Using 100% Retention
(hundredths of an inch)
Type II 24-hour Storm
3-inch Rainfall
Existing Runoff Curve Number
Proposed Runoff Curve Number

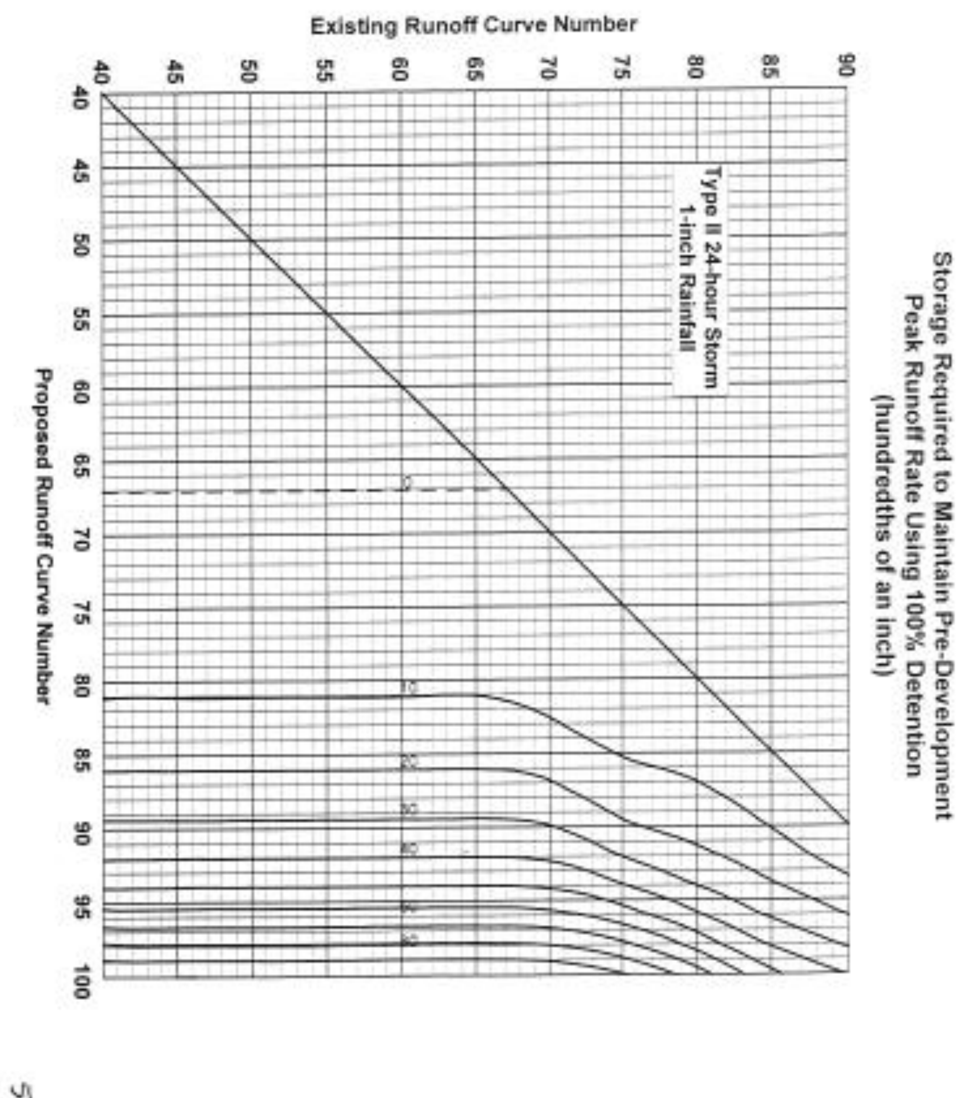

Storage Required to Maintain Pre-Development
Peak Runoff Rate Using 100% Retention
(hundredths of an inch)
Type II 24-hour Storm
4-inch Rainfall
Existing Runoff Curve Number
Proposed Runoff Curve Number


Storage Required to Maintain Pre-Development
Peak Runoff Rate Using 100% Retention
(hundredths of an inch)
Type II 24-hour Storm
5-inch Rainfall
Existing Runoff Curve Number
Proposed Runoff Curve Number

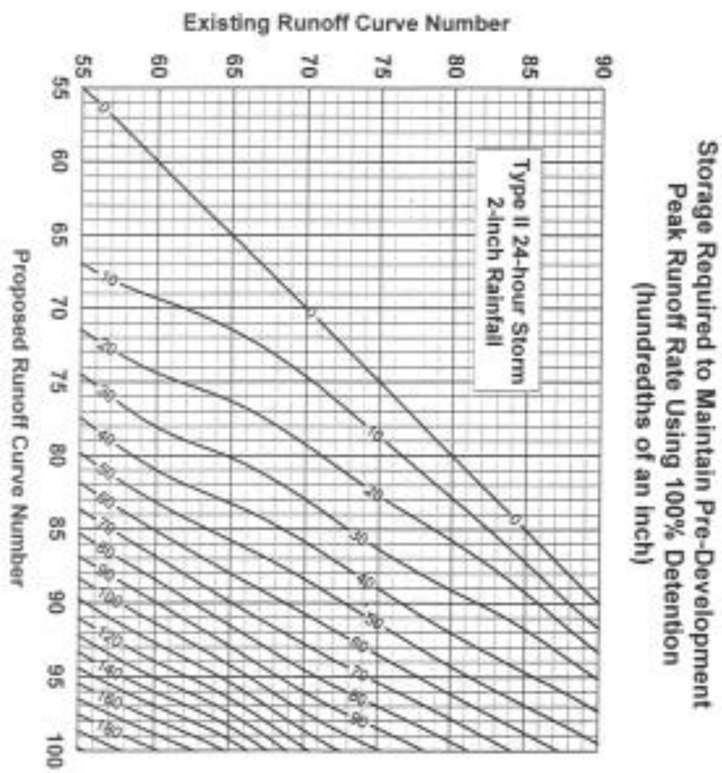

Storage Required to Maintain Pre-Development
Peak Runoff Rate Using 100% Retention
(hundredths of an inch)
Type II 24-hour Storm
6-inch Rainfall
Existing Runoff Curve Number
Proposed Runoff Curve Number


Storage Required to Maintain Pre-Development
Peak Runoff Rate Using 100% Retention
(hundredths of an inch)
Type II 24-hour Storm
7-inch Rainfall
Existing Runoff Curve Number
Proposed Runoff Curve Number

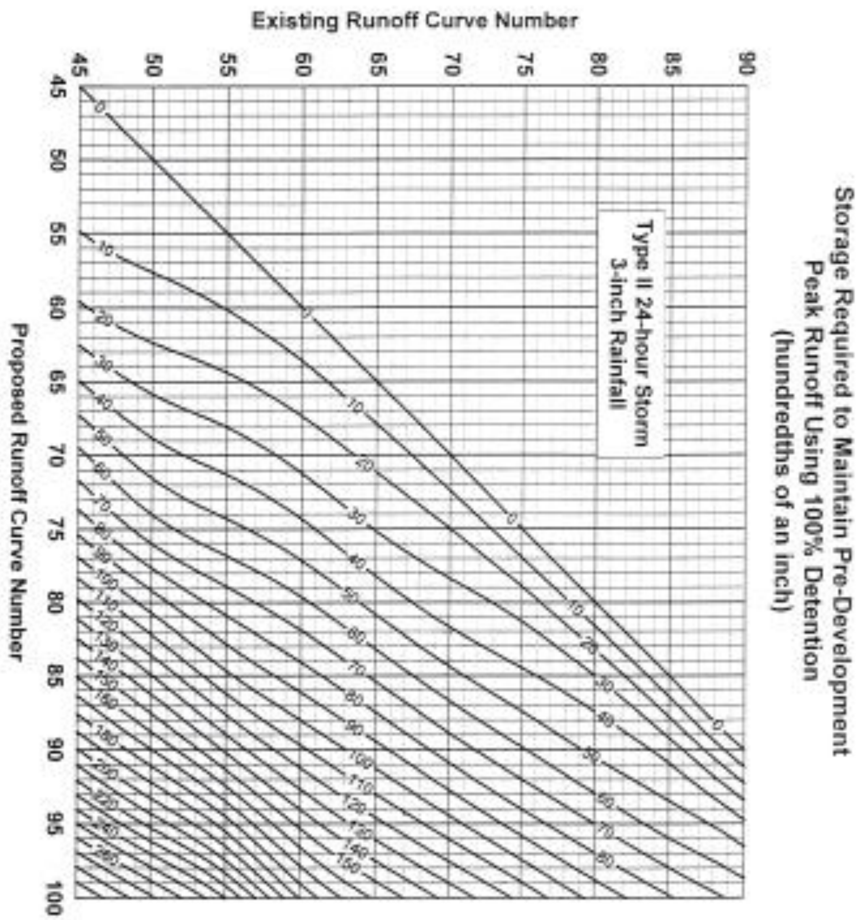
Appendix D: Storage Volume Required to Maintain the Pre-Development Peak Runoff Rate Using 100% Detention Storage - Type 2 24-Hour Storage Chart Series

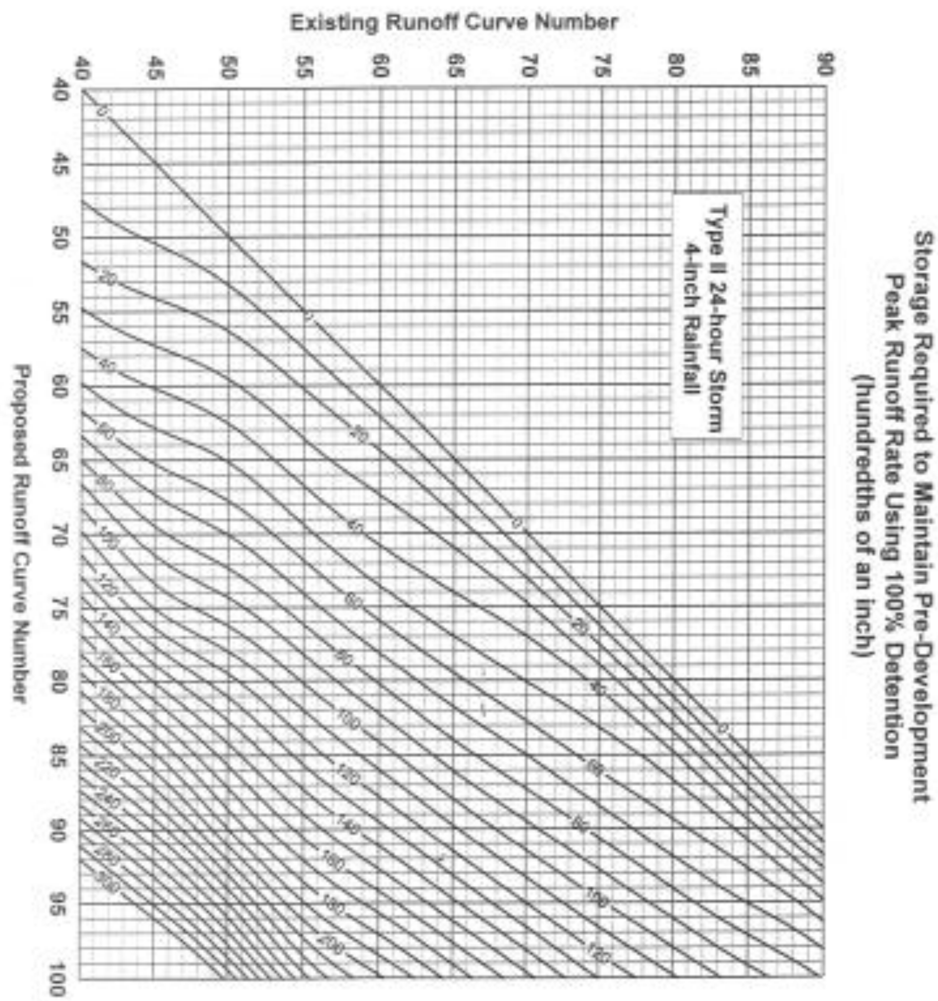


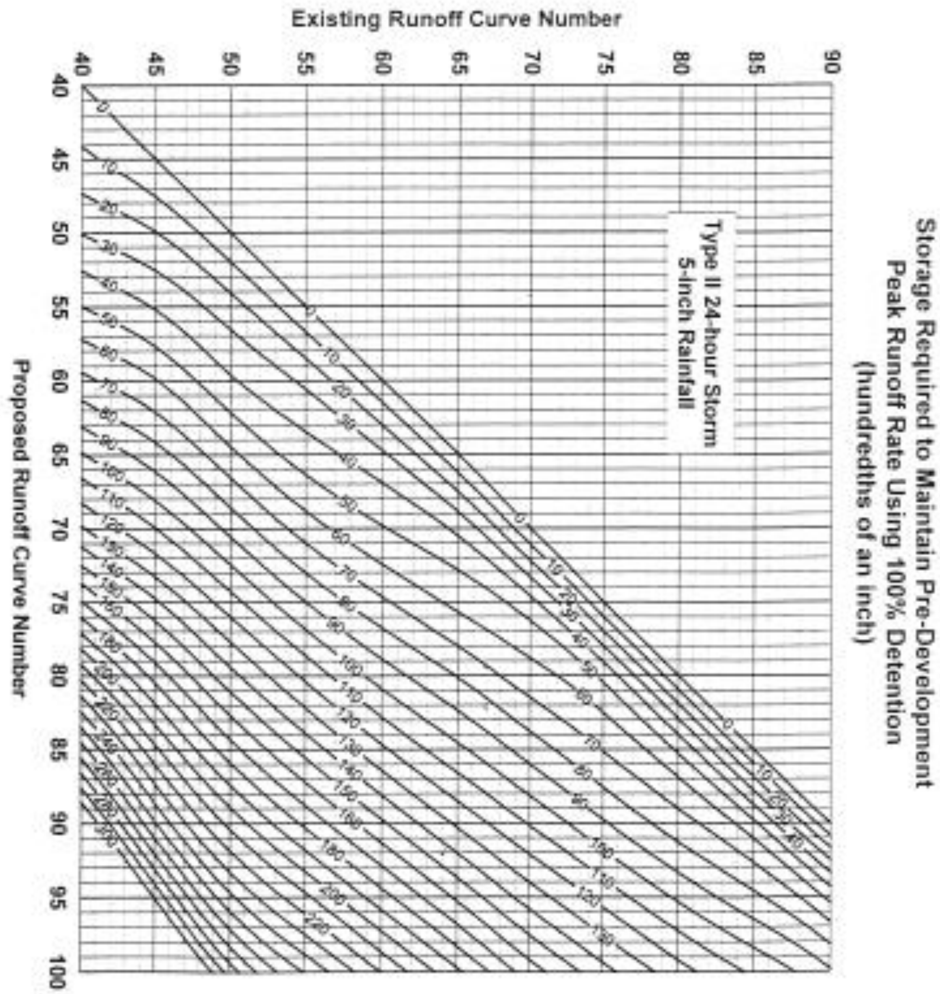
Storage Required to Maintain Pre-Development
Peak Runoff Rate Using 100% Detention
(hundredths of an inch)
Type II 24-hour Storm
1-inch Rainfall
Existing Runoff Curve Number
40
45
50
55
60
65
70
75
80
85
90
Proposed Runoff Curve Number
40
45
50
55
60
65
70
75
80
85
90
95
100



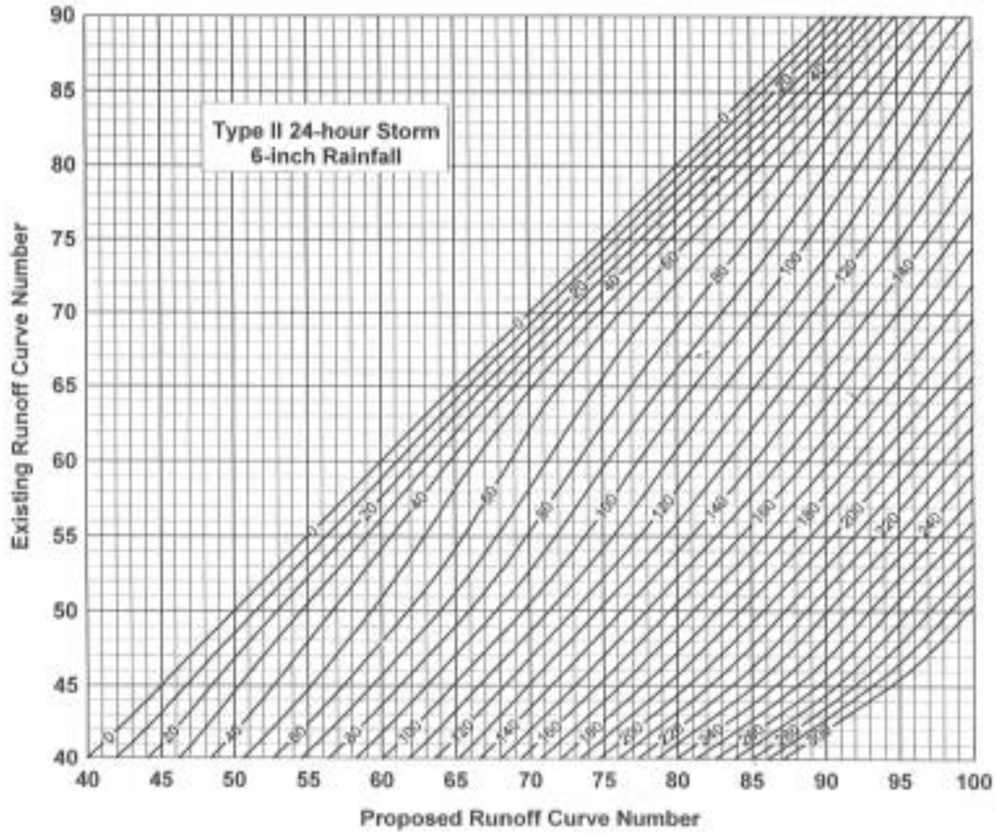
Storage Required to Maintain Pre-Development
Peak Runoff Rate Using 100% Detention
(hundredths of an inch)
Type II 24-hour Storm
2-Inch Rainfall
Existing Runoff Curve Number
Proposed Runoff Curve Number
55
60
65
70
75
80
85
90
95
100

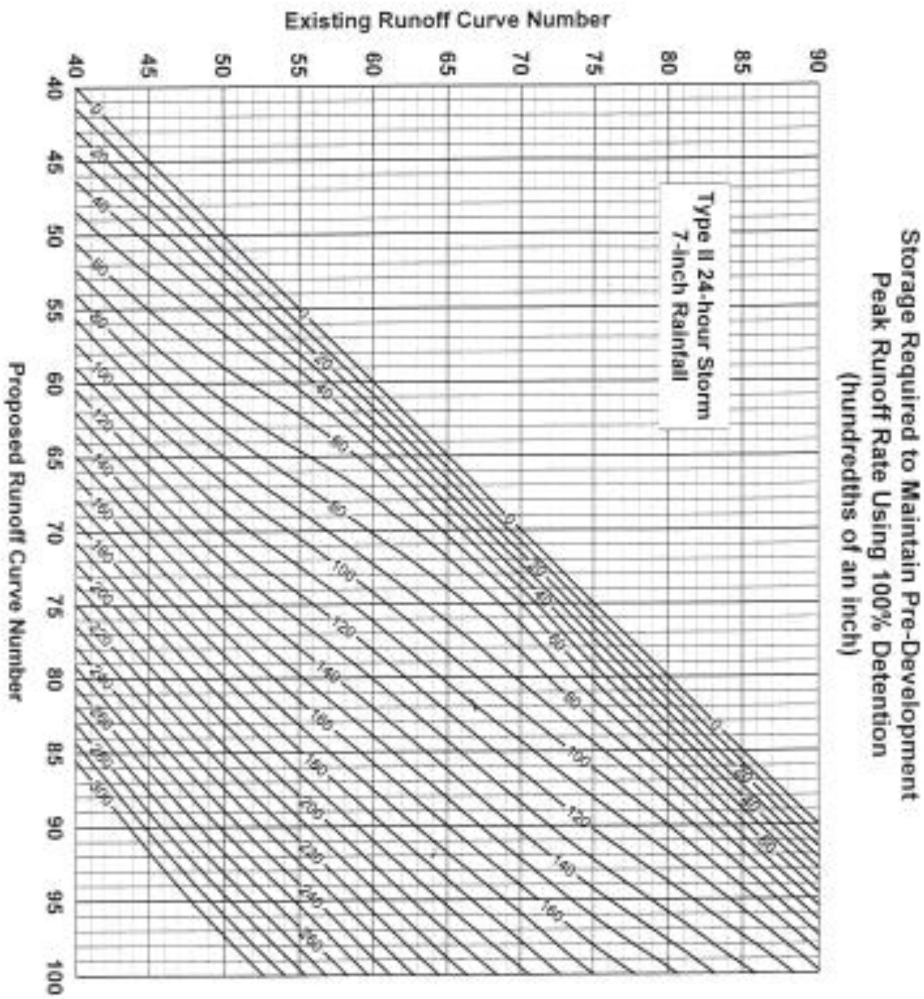

Storage Required to Maintain Pre-Development
Peak Runoff Using 100% Detention
(hundredths of an inch)
Type II 24-hour Storm
3-inch Rainfall
Existing Runoff Curve Number
Proposed Runoff Curve Number


Storage Required to Maintain Pre-Development
Peak Runoff Rate Using 100% Detention
(hundredths of an inch)
Type II 24-hour Storm
4-inch Rainfall
Existing Runoff Curve Number
Proposed Runoff Curve Number


Storage Required to Maintain Pre-Development
Peak Runoff Rate Using 100% Detention
(hundredths of an inch)
Type II 24-hour Storm
5-inch Rainfall
Existing Runoff Curve Number
Proposed Runoff Curve Number
40
45
50
55
60
65
70
75
80
85
90
95
100

Storage Required to Maintain Pre-Development Peak Runoff Rate Using 100% Detention (hundredths of an inch)




Storage Required to Maintain Pre-Development
Peak Runoff Rate Using 100% Detention
(hundredths of an inch)
Type II 24-hour Storm
7-inch Rainfall
Existing Runoff Curve Number
Proposed Runoff Curve Number

Appendix E: Soil Verification Form

MECKLENBURG COUNTY

Land Use and Environmental Services Agency

Water and Land Resources

Water Quality

SOIL VERIFICATION FORM

I, ________________________________, acting as a representative for,
(Name of owner or owner's representative)
____,declare that the soil that is being
(Name of the Company supplying the Amended Soils)
provided to,_______________________________________, meets the standards set
(Name of Company receiving the Amended Soils)
forth in the **Town of Huntersville Water Quality Design Manual,** dated January 1, 2008.

This the _______day of _________________, 20___.

___________________________(Seal)
(Signature of Owner)

Sworn to and subscribed before me this ______day of ___________________, 20___.

My commission expires: _____________________________.

___________________ Notary Public

PEOPLE ● PRIDE ● PROGRESS ● PARTNERSHIPS
2145 Suttle Avenue ● Charlotte, N.C. 28208-5237 ● 980-314-3217
http://waterquality.charmeck.org

Appendix F: LID Mitigation Application

Low Impact Development (LID) Mitigation Application **(Off-Site & Buy-Down Mitigation Options)**
Town of Huntersville

Mitigation Option Requested for Approval : ☐ Off-Site Mitigation ☐ Buy-Down Mitigation

Information Regarding Site Needing Mitigation (must be completed for both Off-Site & Buy-Down Options):

Name of Development:		
Street Name & Number:	Original Tax Parcel:	
Name of Creek System Where Development is Located:		
Total Area of Project (acres):	Total Disturbed Area (acres):	% Built Upon:
Land Development Fee Paid: $	☐ Amendment to Permit #:	
Type of Development: ☐ Commercial ☐ Residential ☐ Mixed Use ☐ Subdivision		
Zoning Designation:		
Resubmittal: ☐ Yes ☐ No If yes provide notification date that resubmittal was required:		
Type of On-Site BMP Installed:		
Pollutant Load Required for Mitigation:		
Owner's Name:		
Owner's Address:		
Owner's Phone Number:	Fax:	
Owner's Email:		

Option #1: Complete for Off-Site Mitigation **(information regarding the site where mitigation is to be performed):**

Name of Site:		
Street Name & Number:	Tax Parcel:	
Name Creek System Where Site is Located:		
Total Area of Site (acres):	Total Area to be Treated (acres):	% Built Upon:
Type of Development: ☐ Commercial ☐ Residential ☐ Mixed Use ☐ Subdivision		
Zoning Designation:		
Resubmittal: ☐ Yes ☐ No If yes provide notification date that resubmittal was required:		
Type Off-Site BMP to be Installed (plans must be attached):		
Pounds of Total Phosphorus (TP) Reduced by the Off-Site Retrofit Project:		
Property Owner's Name:		
Owner's Address:		
Owner's Phone Number:	Fax:	
Owner's Email:		

Option #2: Complete for Buy-Down Mitigation **(obtain from back of form under Option#2):**

1. Pollutant Load Required for Mitigation Over 20 Years =
2. Pollutant Load Over 20 Years x Mitigation Rate ($2,257.78/lb.) =
3. 20 Year Operation and Maintenance Costs ($4,400/acre) =
4. Administrative Costs (12% of total) =
5. Total LID Buy-Down Mitigation Cost =
IMPORTANT: Check must be made payable to applicable Jurisdiction.

This application conveys the information necessary for the review of a request for both off-site and buy-down mitigation. On-site BMPs shall be constructed to achieve 50% removal of total phosphorus. This application shall be reviewed and approved at the same time as the Concept Plan for the project. Approval of this application runs contiguous with the Storm Water Management Permit issued for the site which is valid until the project is complete or three (3) years from issuance of permit, whichever comes first. The information listed on the back of this form must be enclosed for Options 1 or 2 along with a completed application form in order for the application to be considered complete.

Reviewed By: ____ Date: ______________________

☐ Approved ☐ Approved with Modifications ☐ Approved with Performance Reservation (attached)

Issued By: ____ Date: _____________________

Option #1: Off-Site Mitigation Option

Check off the items below and enclose with this application form when requesting approval for the <u>Off-Site LID Mitigation Option</u>. All items must be checked in order for an application to be considered complete.

1. ☐ Provide the following calculations:

1	Project Site Drainage Area (acres)	
2	Phosphorus Loading at Project Site (lbs/acre/year) (select value from Table 3.1 of Huntersville Water Quality Design Manual)	
3	Total Phosphorus Loading at Project Site (lbs/year) (Row 1 x Row 2)	
4	Pollutant Load Required for Mitigation (lbs/year) (Row 3 x 10%)	
6	Mitigation Site Drainage Area (acres)	
7	Phosphorus Loading at Mitigation Site (lbs/acre/year) (select value from Table 3.1 of Huntersville Water Quality Design Manual)	
8	Total Phosphorus Loading at Mitigation Site (lbs/year) (Row 6 x Row 7)	
9	Total Phosphorus Removal Efficiency of BMP at Mitigation Site (%)	
10	Total Phosphorus Loading Reduced by the Mitigation Site (lbs/year) (Row 8 x Row 9)	
11	Pollutant Load Mitigated (%) ((Row 10 / Row 4) x 100)	

2. ☐ Six (6) sets of plans with two (2) sets of calculations for the off-site BMP retrofit project. All designs must be in accordance with the approved Design Manual. All plans and calculations must be sealed by a professional designer. All plans must contain the following:
   - Details showing the structures dimensions, including top and bottom of storage area as well as depth and storage volume;
   - BMP table with specifics on each BMP including calculations illustrating compliance. BMPs shall be named on plans as follows: "Project Name – BMP Type – Number";
   - Easements for all BMPs and drainage ways;
   - Existing and proposed paved roads, buildings, structures and utilities;
   - Basin contours labeled and tied into existing contours;
   - Construction sequence;
   - North arrow;
   - Vicinity map;
   - Parcel Tax Number;
   - Jurisdiction;
   - Legible scale;
   - Property boundary and adjoining property boundaries and owners;
   - Watershed District; and
   - Delineation of on-site drainage areas including number of acres.
3. ☐ A legally valid instrument demonstrating that the applicant has land rights to perform the BMP retrofit project on the property.
4. ☐ A Phase I environmental site assessment must be provided indicating that there are no areas of environmental concern on or immediately adjacent to the site.
5. ☐ An Operation and Maintenance Agreement and Maintenance Plan must be attached to the application form for each BMP included in the project.

Option #2: Buy-Down Mitigation Option

Provide a check payable to the Town of Huntersville in the amount shown in Line 9.

1. ☐ Provide the following calculations:

1	Project Ste Drainage Area (acres)	
2	Phosphorus Loading (lbs/acre/year) (select value from Table 3.1 of Huntersville Water Quality Design Manual)	
3	Total Phosphorus Loading for the Site (lbs/year) (Row 1 x Row 2)	
4	Pollutant Load Required for Mitigation (lbs/year) (Row 3 x 10%)	
5	Pollutant Load Required for Mitigation Over the 20 Year Life Span of the BMP (lbs) (Row 4 x 20)	
6	Pollutant Load Over 20 Years x Mitigation Rate ($) (Row 5 x $2,257.78/lb.)	
7	20 Year Operation and Maintenance Costs at $4,400/Acre ($) (Row 1 x $4,400)	
8	Administrative Costs at 12% of Total ($) ((Rows 6 + 7) x 0.12)	
9	Total LID Buy-Down Mitigation Cost ($) (Rows 6 + 7 + 8)	

Application Submittal Requirements:

This application must be submitted at the same time and attached to the Concept Plan Application form.