Chapter 8 – Appendices

Appendix A – Wake County Hydrologic Soil Groups and Proposed Development Curve Numbers

Table A-1 Wake County Hydrologic Soil Groups

MAP SYMBOL	SOIL SERIES & DESCRIPTION	HYDROLOGIC SOIL GROUPS (HSG)*
AaA	Altavista fine sandy loam, 0 to 4 percent slopes, rarely flooded	C
ApB	Appling sandy loam, 2 to 6 percent slopes	B
ApC	Appling sandy loam, 6 to 10 percent slopes	B
AuA	Augusta fine sandy loam, 0 to 2 percent slopes, rarely flooded	C/D
BbA	Bibb sandy loam, 0 to 2 percent slopes, frequently flooded	A/D
CaB	Carbonton-Brickhaven complex, 2 to 6 percent slopes	D
CaC	Carbonton-Brickhaven complex, 6 to 10 percent slopes	D
CaD	Carbonton-Brickhaven complex, 10 to 15 percent slopes	D
CcC	Carbonton-Brickhaven- Urban land complex, 0 to 10 percent slopes	D
CeB	Cecil sandy loam, 2 to 6 percent slopes	A
CeC	Cecil sandy loam, 6 to 10 percent slopes	A
CfC	Cecil-Urban land complex, 2 to 10 percent slopes	A
ChA	Chewacla and Wehadkee soils, 0 to 2 percent slopes, frequently flooded	B/D
CrB	Creedmoor-Green Level complex, 2 to 6 percent slopes	C/D
CrC	Creedmoor-Green Level complex, 6 to 10 percent slopes	C/D
CrD	Creedmoor-Green Level complex, 10 to 15 percent slopes	C/D
CuC	Creedmoor-Green Level-Urban land complex, 2 to 10 percent slopes	C/D
DaA	Dorian sandy loam, 0 to 4 percent slopes, rarely flooded	C
DAM	Dam	
DoA	Dothan loamy sand, 0 to 2 percent slopes	C
DoB	Dothan loamy sand, 2 to 6 percent slopes	C
DuB	Dothan-Urban land complex, 0 to 6 percent slopes	C
EnB	Enon fine sandy loam, 2 to 6 percent slopes	C
EnC	Enon fine sandy loam, 6 to 10 percent slopes	C
EnD	Enon fine sandy loam, 10 to 15 percent slopes	C
FrB	Fuquay loamy sand, 0 to 6 percent slopes	A
FuB	Fuquay-Urban land complex, 0 to 6 percent slopes	A
GeB	Georgeville silt loam, 2 to 6 percent slopes	C
GeC	Georgeville silt loam, 6 to 10 percent slopes	C
GoA	Goldsboro sandy loam, 0 to 2 percent slopes	C
GrC	Gritney sandy loam, 6 to 10 percent slopes	D
HeB	Helena sandy loam, 2 to 6 percent slopes	D
HrB	Herndon silt loam, 2 to 6 percent slopes	B

MAP SYMBOL	SOIL SERIES & DESCRIPTION	HYDROLOGIC SOIL GROUPS (HSG)*
HrC	Herndon silt loam, 6 to 10 percent slopes	B
HrD	Herndon silt loam, 10 to 15 percent slopes	B
LyA	Lynchburg sandy loam, 0 to 2 percent slopes	C/D
MaB	Madison sandy loam, 2 to 6 percent slopes	C
MaC	Madison sandy loam, 6 to 10 percent slopes	C
MaD	Madison sandy loam, 10 to 15 percent slopes	C
MaE	Madison sandy loam, 15 to 25 percent slopes	C
MdB	Mayodan sandy loam, 2 to 6 percent slopes	C
MdC	Mayodan sandy loam, 6 to 10 percent slopes	C
MrA	Merry Oaks-Moncure complex, 0 to 2 percent slopes, occasionally flooded	C/D
NaD	Nanford silt loam, 10 to 15 percent slopes	C
NaE	Nanford silt loam, 15 to 25 percent slopes	C
PaC	Pacolet sandy loam, 6 to 10 percent slopes	B
PaD	Pacolet sandy loam, 10 to 15 percent slopes	B
PaE	Pacolet sandy loam, 15 to 25 percent slopes	B
PbD	Pacolet-Urban land complex, 10 to 15 percent slopes	B
PkD	Pinoka gravelly fine sandy loam, 4 to 15 percent slopes	B
PkF	Pinoka gravelly fine sandy loam, 15 to 30 percent slopes	B
RaA	Rains sandy loam, 0 to 2 percent slopes	A/D
RgB	Rawlings-Rion complex, 2 to 6 percent slopes	C
RgC	Rawlings-Rion complex, 6 to 10 percent slopes	C
RgD	Rawlings-Rion complex, 10 to 15 percent slopes	C
RkA	Riverview fine sandy loam, 0 to 2 percent slopes, occasionally flooded	B
RoA	Roanoke loam, 0 to 2 percent slopes, occasionally flooded	C/D
UdE	Udorthents loamy, 0 to 25 percent slopes	C
Ur	Urban land	
VaB	Vance sandy loam, 2 to 6 percent slopes	D
VaC	Vance sandy loam, 6 to 10 percent slopes	D
W	Water	
WaB	Wake-Rolesville complex, 2 to 6 percent slopes, very rocky	D
WaC	Wake-Rolesville complex, 6 to 10 percent slopes, very rocky	D
WaD	Wake-Rolesville complex, 10 to 15 percent slopes, very rocky	D
WaE	Wake-Rolesville complex, 15 to 25 percent slopes, very rocky	D
WeB	Wedowee sandy loam, 2 to 6 percent slopes	B
WeC	Wedowee sandy loam, 6 to 10 percent slopes	B
WeD	Wedowee sandy loam, 10 to 15 percent slopes	B
WeE	Wedowee sandy loam, 15 to 25 percent slopes	B

MAP SYMBOL	SOIL SERIES & DESCRIPTION	HYDROLOGIC SOIL GROUPS (HSG)*
WfB	Wedowee-Saw complex, 2 to 6 percent slopes	B
WgB	Wedowee-Urban land complex, 2 to 6 percent slopes	B
WgC	Wedowee-Urban land complex, 6 to 15 percent slopes	B
WhB	White Store-Polkton complex, 2 to 6 percent slopes	D
WhC	White Store-Polkton complex, 6 to 10 percent slopes	D
WhD	White Store-Polkton complex, 10 to 15 percent slopes	D
WkF	Wilkes loam, 15 to 30 percent slopes	D

*If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Note: Web Soil Survey (series info) http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

Table A-2 Wake County Proposed Development Curve Numbers

LAND USE	Curve Numbers by Hydrologic Soil Group			
	A	B	C	D
COMMERCIAL				
Parking lot	98	98	98	98
Roof	98	98	98	98
Open/Landscaped	39	61	74	80
INDUSTRIAL				
Parking lot	98	98	98	98
Roof	98	98	98	98
Open/Landscaped	39	61	74	80
TRANSPORTATION				
High Density (interstate, main)	98	98	98	98
High Density Grassed Right-of-ways	80	80	80	80
Low Density (secondary, feeder)	98	98	98	98
Low Density Grassed Right-of-ways	80	80	80	80
Rural	98	98	98	98
Rural Grassed Right-of-ways	80	80	80	80
Sidewalk	98	98	98	98
MISC. PERVIOUS				
Managed pervious (Open Space)	39	61	74	80
Unmanaged (pasture)	39	61	74	80
Woods	30	55	70	77
RESIDENTIAL				
Roadway	98	98	98	98
Grassed Right-of-ways	80	80	80	80
Driveway	98	98	98	98
Parking lot	98	98	98	98
Roof	98	98	98	98
Sidewalk	98	98	98	98
Lawn	39	61	74	80
Managed pervious (Open Space)	39	61	74	80
Woods	30	55	70	77
LAND TAKEN UP BY BMP	39	61	74	80
JURISDICTIONAL LANDS				
Natural wetland	30	55	70	77
Riparian buffer	39	61	74	80
Open water	0	0	0	0

Note: Wake County's policy regarding the right-of-way areas includes an assumption of compaction of these areas. Therefore, the grassed portion of the right-of-way is assigned the curve number for open space in D soils to account for this assumption of compaction.

Appendix B – Downstream Impact Analysis Scenarios Using the 10% Rule

Purpose: The purpose of the Downstream Impact Analysis is to determine if the project will cause any unintentional additional impacts on flooding or channel degradation downstream of the project site.

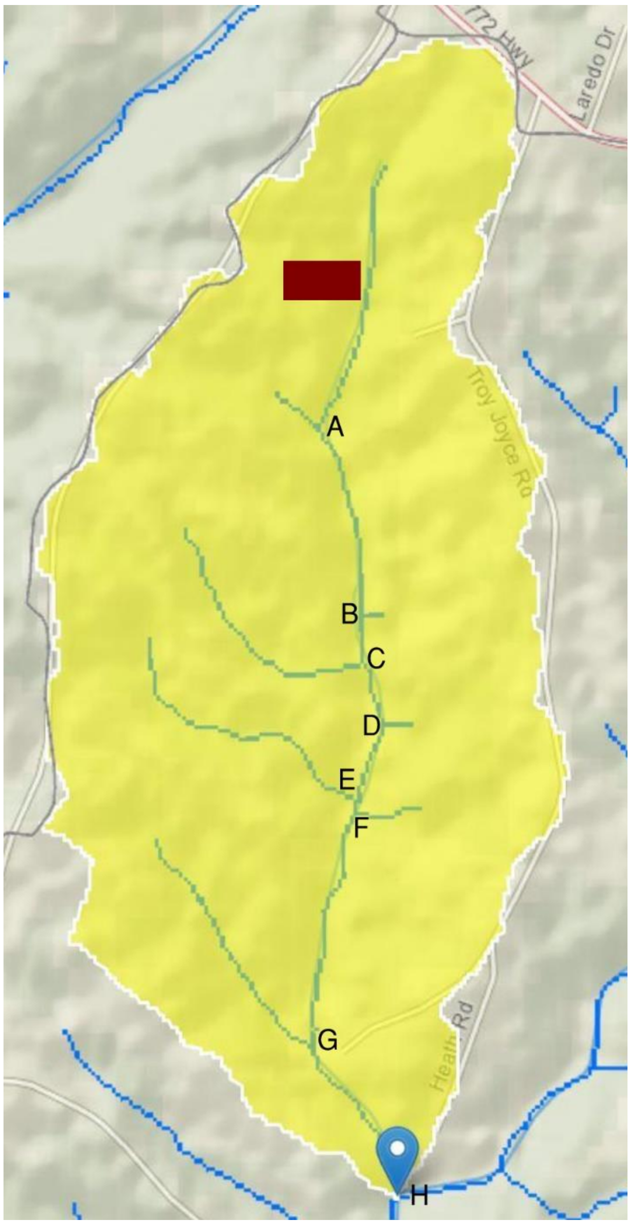
Zone of Influence: The point downstream from a proposed development where the discharge from that development no longer has a significant impact on the receiving stream or storm drainage system.
Beyond this zone of influence, stormwater effects of the site become relatively small and insignificant compared to the runoff from the total drainage area.
The general rule of thumb is that the zone of influence for a project can be considered to be the point where the project/site area is equal to (or less than) 10% of the total drainage area to that point.

To Determine Zone of Influence:

The following examples are used to illustrate how to determine the Zone of Influence (or 10% point) and the points which must be used for the downstream impact analysis.
Note that both the size of the development project AND its location within the overall watershed are key factors in determining the limits of the required downstream impact analysis.
These examples are very simplified but are intended to illustrate the concepts involved in these determinations.

Example 1: Project Apple is a 30-acre proposed development located within the hypothetical watershed above junction A as shown below.

For a 30-acre site, it's proposed zone of influence – or 10% point – would be at 300 acres of drainage area. So we must look downstream of Project Apple to find the point where the drainage acre that includes the project is at least 300 acres. This will be somewhere between junction D and E in our hypothetical watershed. The downstream analysis should then be competed through junction E – since it is the first junction that would meet or exceed the necessary 300-acre zone of influence.



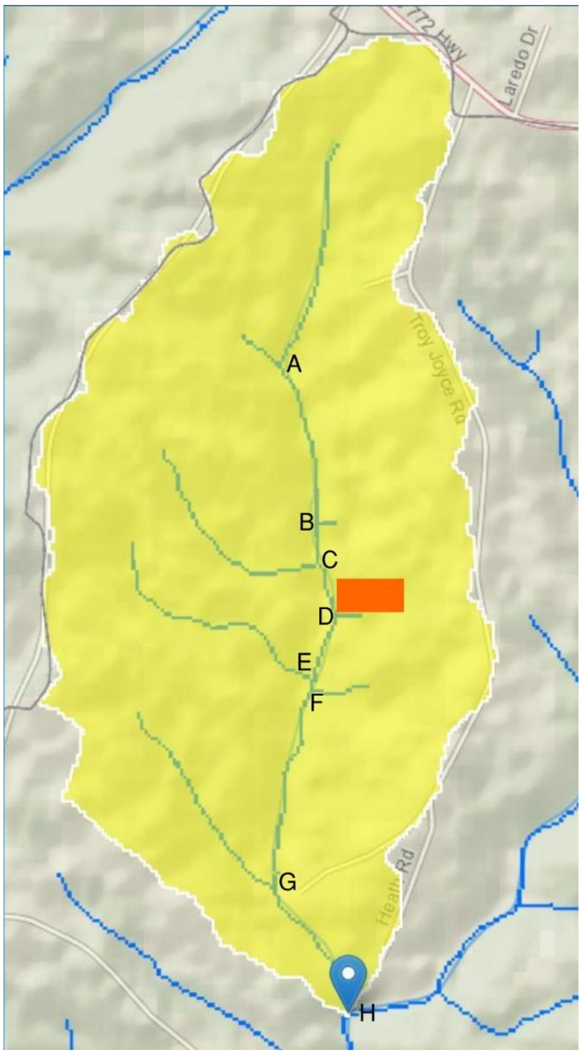
Junction in Watershed	Total Drainage Area
A	102.4 ac
B	166.4 ac
C	224.0 ac
D	249.6 ac
E	313.6 ac
F	339.2 ac
G	454.4 ac
H	486.4 ac

For 30-acre Project Apple, the downstream analysis would include the following points of analysis:

- Outlet of Project Apple
- Junction A
- Junction B
- Junction C
- Junction D
- Junction E

<u>Example 2:</u> Project Orange is another 30-acre proposed development located within the hypothetical watershed just above junction D.

For a 30-acre site, it's proposed zone of influence – or 10% point – would also be at 300 acres of drainage area. So we must look <u>downstream of Project Orange</u> to find the point where the drainage acre that includes the project is at least 300 acres. This will be somewhere between junction D and E in our hypothetical watershed. The downstream analysis should then be competed through junction E – since it is the first junction that would meet or exceed the necessary 300-acre zone of influence.

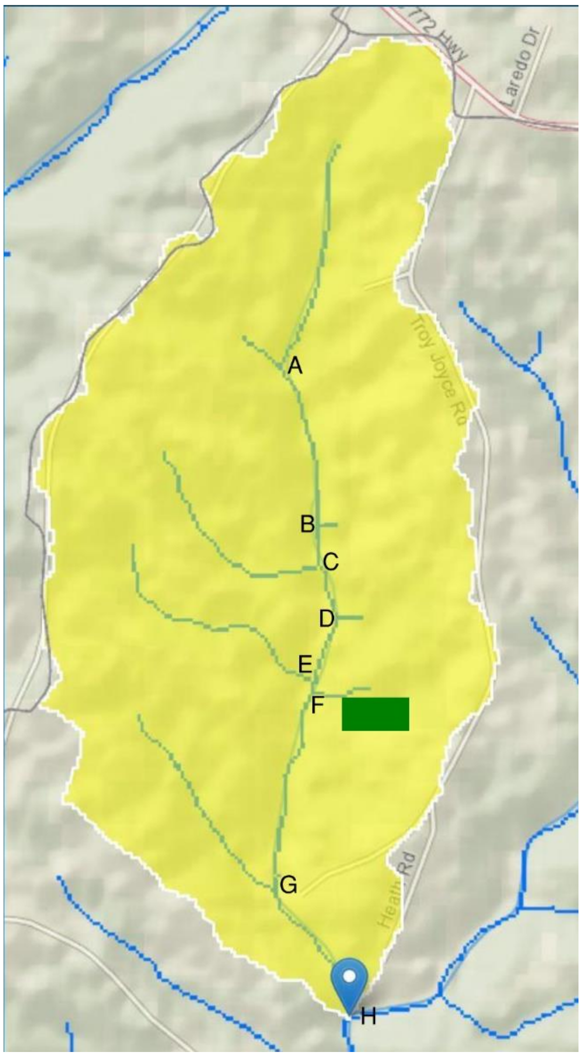


Junction in Watershed	Total Drainage Area
A	102.4 ac
B	166.4 ac
C	224.0 ac
D	249.6 ac
E	313.6 ac
F	339.2 ac
G	454.4 ac
H	486.4 ac

For 30-acre Project Orange, the downstream analysis would include the following points of analysis:

- Outlet of Project Orange
- Junction D
- Junction E

Example 3: Project Kiwi is another 30-acre proposed development located along a tributary draining toward junction F within the hypothetical watershed.
For a 30-acre site, it's proposed zone of influence – or 10% point – would also be at 300 acres of drainage area. So we must look downstream of Project Kiwi to find the point where the drainage acre that includes the project is at least 300 acres. In this case, project outlets into a tributary, and junction F is the first downstream junction. At this point, the total drainage area is 339.2 acres. For Project Kiwi, the downstream impact analysis will end at junction F.



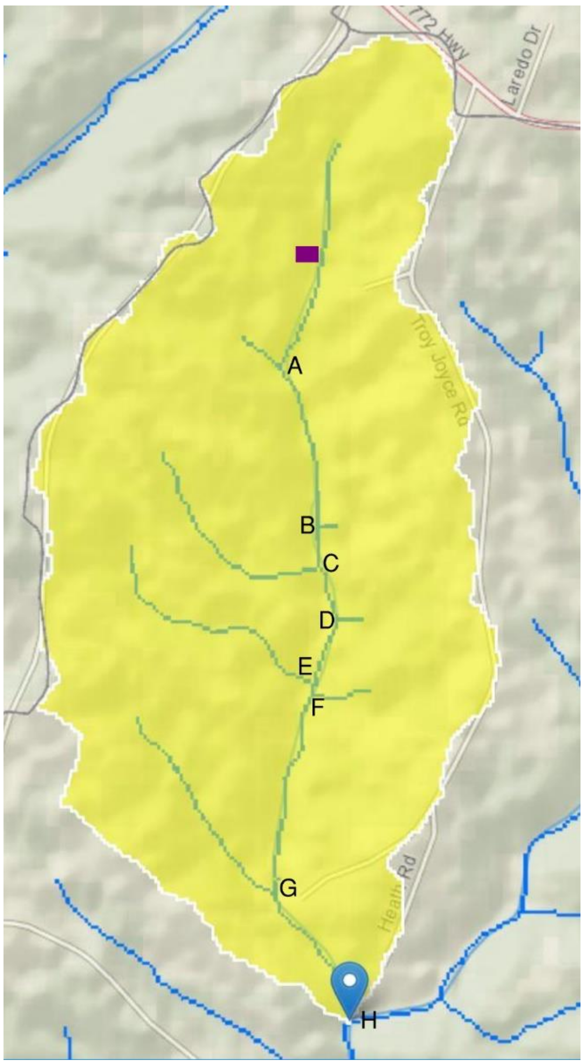
Junction in Watershed	Total Drainage Area
A	102.4 ac
B	166.4 ac
C	224.0 ac
D	249.6 ac
E	313.6 ac
F	339.2 ac
G	454.4 ac
H	486.4 ac

For 30-acre Project Kiwi, the downstream analysis would include the following points of analysis:

- Outlet of Project Kiwi
- Junction F

<u>**Example 4:**</u> Project Plum is a 5-acre proposed development located along a tributary draining toward junction A within the hypothetical watershed. The engineer of record has performed a delineation showing that, at the project's outlet to the tributary, there is a total drainage area of 47.2 acres.

Unfortunately, for a 5-acre project, the 10% point would be at a location where the total drainage area including the project was at least 50 acres. So we must look <u>downstream of Project Plum</u> to find the point where the drainage acre that includes the project is at least 50 acres. At the first junction after the project (junction A), the total drainage area is 102.4 acres. For Project Plum, the downstream impact analysis will end at junction A.



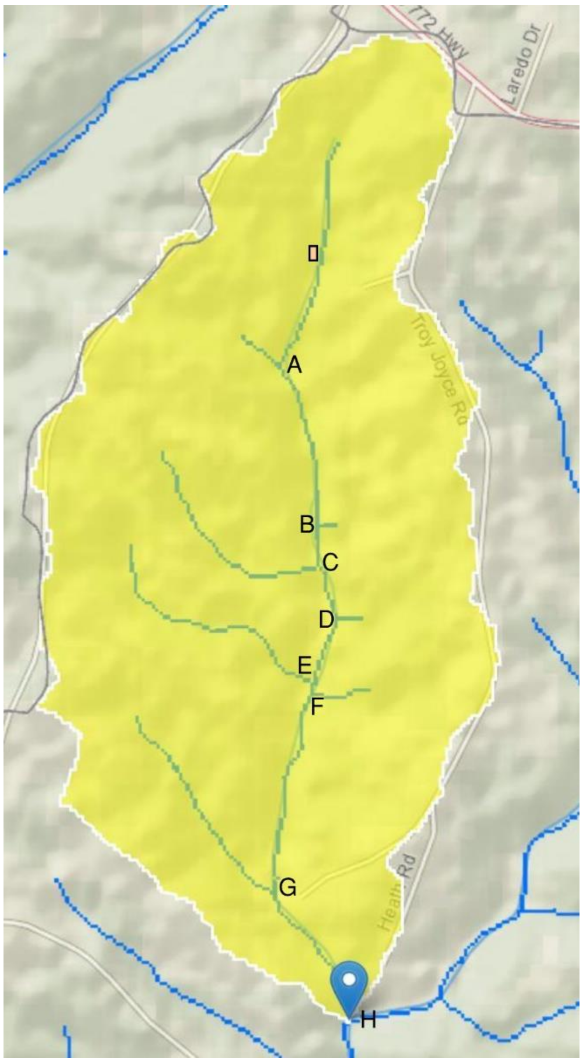
Junction in Watershed	Total Drainage Area
A	102.4 ac
B	166.4 ac
C	224.0 ac
D	249.6 ac
E	313.6 ac
F	339.2 ac
G	454.4 ac
H	486.4 ac

For 5-acre Project Plum, the downstream analysis would include the following points of analysis:

- Outlet of Project Plum
- Junction A

Example 5: The funding for Project Plum (Example 4) fell through. A new developer now plans a smaller 2-acre development called Project Peach at that same location along a tributary draining toward junction A within the hypothetical watershed. The engineer of record has performed a delineation showing that, at its outlet to the tributary, there is a total drainage area of 47.2 acres.

For a 2-acre project, the 10% point would be at a location where the total drainage area including the project was at least 20 acres. For Project Peach, this means that only its outlet to the tributary must be analyzed in the downstream analysis.



Junction in Watershed	Total Drainage Area
A	102.4 ac
B	166.4 ac
C	224.0 ac
D	249.6 ac
E	313.6 ac
F	339.2 ac
G	454.4 ac
H	486.4 ac

For 2-acre Project Peach, the downstream analysis would include the following points of analysis:

- Outlet of Project Peach

<u>Downstream Impact Analysis Process:</u>
The downstream impact analysis must include the assumptions, results and supporting calculations to show safe passage of post-development design flows downstream for the 10-year design storm. This analysis shall be performed at the outlet(s) of the site, and downstream at each tributary junction to the point(s) in the conveyance system where the area of the portion of the site draining into the system is less than or equal to ten percent of the total drainage area above that point.

The general procedure is as follows:

1. Determine all points of discharge from the site. These points will be used as the first point(s) of analysis for the downstream impact analysis. Identify pre- and post-development site conditions.

Note that if the discharge point(s) from the site do not have a clearly defined cross section, they shall be considered as either shallow concentrated flow or channelized flow. Sheet flow discharges will not be accepted for analysis purposes.

2. Using a topographic map, determine the point(s) downstream where the proposed site area – or the portion of the site area in that drainage area - equals ten percent of the total drainage area, called the 10% point (or “zone of influence”). Identify all tributary junctions between the downstream site boundary/site outlet(s) and the 10% point. All points identified, as well as the outlet(s) of the site, are known as 10% rule comparison points. *[For assistance with this concept, please refer to the examples in the previous section of this document.]*

3. Using a hydrologic model with existing land uses, determine the pre-development peak runoff rate (cubic feet per second) for the 10-year, 24-hour design storm event at each comparison point. Note that the same hydrologic analysis method shall be used for both pre- and post-development discharge calculations.
    - Offsite areas should be modeled as “full build-out” for both the pre-and post-development cases.
    - An accurate estimation of the time of concentration is key in the downstream impact analysis. Large detention structures (including stormwater control measures) within the drainage area will impact the time of concentration and should be considered in the analysis. For projects that discharge directly into a FEMA studied stream, these structures should already be accounted for in the hydrologic models used by those studies. For projects that do not discharge directly to a FEMA studied stream, the engineer performing the analysis will need to use best available information (aerial topography information, field visits, surveys, or existing plans) to model and account for these structures within the watershed.
    - An approximate curve number is used because the actual peak flow is not key for initial analysis. Only the increase or decrease is important. The accuracy in curve number determination is not as significant as an accurate estimate of the time of concentration.

4. Insert the proposed site design and proposed stormwater control measures (SCMs) for the project into the land uses and determine the post-development peak runoff rate for the 10-year, 24-hour design storm at each comparison point.

5. If the post-development peak discharge rate is equal to or less than pre-development conditions at all comparison points, no further analysis is required.

6. If the 10-year, 24-hour post-development peak discharge rate is greater than the pre-development peak discharge rate at any comparison point, then one of the following actions must be taken:

    a. Revise the site plan for the proposed site to incorporate better use of natural features, design additional structural control facilities, reduce impervious cover, or alter the timing of peak flows to lower post-development flows at each comparison point to pre-development levels; or

    b. Obtain a flow easement from downstream property owners through the ten percent point where the post-development peak discharge rate is higher than the pre-development peak discharge rate.

Additional Resources:

The following resources may clarify the general process of downstream impact analyses (or downstream assessments). Note, however, that the standards and requirements identified in these resources may differ from those of Wake County's required analysis. These links are being provided to assist with conceptual understanding only.

Integrated Stormwater Management (iSWM) (nctcog.org) - "Downstream Assessment Analysis"

Georgia Stormwater Shorts: Episode 2: Downstream Analysis - YouTube

Appendix C – Wake County Hybrid Tool

WAKE COUNTY STORMWATER HYBRID DESIGN TOOL OVERVIEW

Engineers complete the Wake County Stormwater Hybrid Design Tool by inputting site information, site land uses and time of concentration data by drainage area for pre and post-development conditions.

Target Curve Number (TCN)

Developers must manage residential runoff for post- development to ensure the site will not exceed the designated curve numbers, in accordance with procedures specified in the *United States Department of Agriculture, Natural Resource Conservation Service, Technical Release 55, Urban Hydrology for Small Watersheds* (TR-55) [*Wake County UDO, Article 9*]. While land uses and hydrologic soil groups (HSGs) are input by engineers by drainage area, the tool calculates the target curve number and post development curve number for the site as a whole. The difference between the two numbers translates to a volume that must be detained for the site. The hybrid tool calculates and flags the volume that is the developer's responsibility to detain. For more information on TCN see Section 4, Stormwater Design Principles.

Peak Flow

Engineers are responsible for inputting land use and time of concentration information and the Tool will calculate the associated peak flows for pre and post development. If runoff leaves the site at several locations, the engineer must conduct a separate analysis for each outfall and enter site information by individual drainage areas.

The hybrid tool calculates and flags peak flow increases requiring potential attenuation using the TR-55 Graphical Peak Discharge Method for Type II Distribution. The tool does not calculate and perform routing for BMP design and engineers are required to provide their own drainage area maps, stormwater model and supporting calculations to show peak flow compliance with state rules. For more information on peak flow see Section 4, Stormwater Design Principles.

Nutrient Loading

Nutrient loading calculations are directly from the Jordan/Fall Nutrient Accounting Tool and were reviewed and approved by the NC Department of Water Quality as part of Wake County's submittal for compliance with the Falls Lake and Jordan Lake Nutrient Strategies. For more information on nutrient loading see Section 4, Stormwater Design Principles.