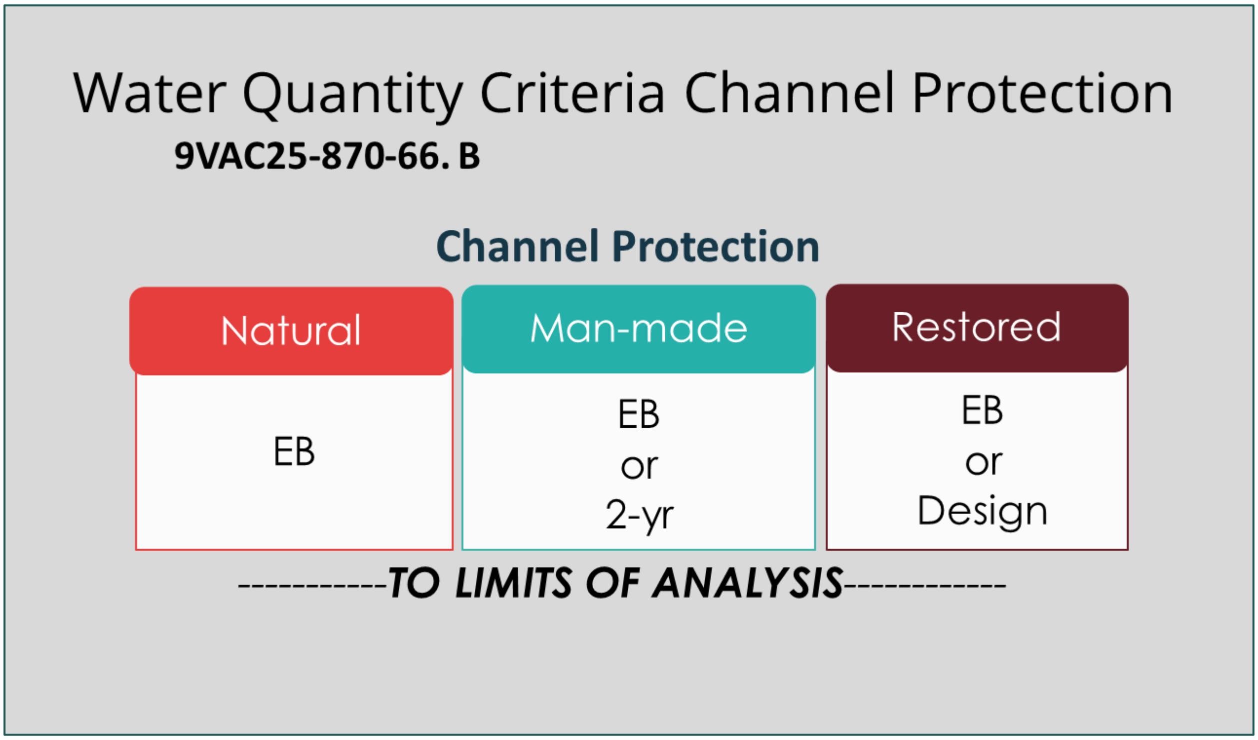
Module 14: Channel and Flood Protection

Objectives

- Evaluate peak runoff rate and runoff volume for compliance with the Energy Balance equation.
- State the state regulatory requirements for channel protection and flood protection.
- Describe the runoff volume reduction credits built into the Virginia Runoff Reduction Method and how they are applied to the quantity control requirements for Channel and Flood Protection.
- Explain the concept of the “Stormwater Conveyance System” as applied in the quantity control requirements for Channel and Flood Protection.
- Discuss the “Energy Balance” concept, equation, and application.
- Recognize the Curve Number Adjustment as applied using the Virginia Runoff Reduction Method.

14a. Channel Protection Criteria and the Energy Balance Method



The Channel Protection Criteria is broken into three types of receiving Stormwater Conveyance Systems as follows:

Manmade Stormwater Conveyance System

Photo: Center for Watershed Protection

Photo: Center for Watershed Protection

A Manmade Stormwater Conveyance System is defined as a pipe, ditch, vegetated swale, or other stormwater conveyance system constructed by man except for restored stormwater conveyance systems.

The Channel Protection criteria for a manmade conveyance system (**9VAC25-870-66.1)**:

- The manmade stormwater conveyance system shall convey the postdevelopment peak flow rate from the two-year 24-hour storm event without causing erosion of the system. Detention of stormwater or downstream improvements may be incorporated into the approved land-disturbing activity to meet this criterion, at the discretion of the VSMP authority; or
- The peak discharge requirements for concentrated stormwater flow to natural stormwater conveyance systems (Energy Balance) shall be met.

Non-erosive capacity for 2-year peak flow **to the Limits of Analysis <u>OR</u>**
Energy Balance (Natural Stormwater Conveyance)

Restored Stormwater Conveyance System

Photo: Williamsburg Environmental Group

Photo: City of Charlottesville

Restored stormwater conveyance system is defined as a conveyance system that has been designed and constructed using natural channel design concepts. Restored stormwater conveyance systems include the main channel and the flood-prone area adjacent to the main channel.

The Channel Protection criteria for a restored conveyance system (**9VAC25-870-66.2)**:

When stormwater from a development is discharged to a restored stormwater conveyance system that has been restored using natural design concepts, following the land-disturbing activity, either:

- The development shall be consistent, in combination with other stormwater runoff, with the design parameters of the restored stormwater conveyance system that is functioning in accordance with the design objectives; or
- The peak discharge requirements for concentrated stormwater flow to natural stormwater conveyance systems in subdivision 3 of this subsection shall be met.

Development (density, scale, etc.) and peak flow consistent with design parameters of the restored system **to the Limits of Analysis <u>OR</u>**
Energy Balance Method (Natural Stormwater Conveyance)

Limits of Analysis for Channel Protection

9VAC25-870-66, 9VAC25-870-72

The limits of analysis establish how far downstream the designer must verify the adequacy of the Stormwater Conveyance System. The requirement to analyze the downstream system, and therefore the criteria for how far downstream to carry the analysis applies only in cases where the energy balance criteria is not being utilized.

Channel protection analysis is carried to a point where:

a. The site's contributing drainage area is less than or equal to 1.0% of the total watershed area draining to a point of analysis in the downstream stormwater conveyance system; or

b. Based on peak flow rate, the site's peak flow rate from the 1-year 24-hour storm event is less than or equal to 1.0% of the existing peak flow rate from the 1-year 24-hour storm event prior to the implementation of any stormwater quantity control measures.

The designer must analyze the stormwater conveyance system using *acceptable hydrologic and hydraulic methodologies* to the defined limit of analysis.

When the Energy Balance criterion is applied, no analysis of the downstream Stormwater Conveyance System is required.

Natural Stormwater Conveyance Systems

Photo: Ellanor C. Lawrence Park Fairfax, County

Natural stormwater conveyance system is defined as the main channel of a natural stream and the flood-prone area adjacent to the main channel.

Restore using natural channel design **OR**
Energy Balance (1-year storm event) **OR**
Safe Harbor Provision (from SWM Law § 62.1-44.15:28.10)

The Channel Protection criteria for a natural conveyance system (**9VAC25-870-66.3)**:

When stormwater from a development is discharged to a natural stormwater conveyance system, the maximum peak flow rate from the **one-year 24-hour storm** following the land-disturbing activity shall be calculated either:

In accordance with the following methodology (**Energy Balance**):

$$Q_{1\text{-yr-Developed}} \leq I.F.*(Q_{1\text{-yr-Pre-developed}} * RV_{1\text{-yr-Pre-Developed}})/RV_{1\text{-yr-Developed}}$$

Under no condition shall:

$$Q_{1\text{-yr-Developed}} > Q_{1\text{-yr-Pre-Developed}}$$

$$Q_{1\text{-yr-Developed}} < (Q_{1\text{-yr-Forest}} * RV_{1\text{-yr-Forest}})/RV_{1\text{-yr-Developed}};$$

where

I.F. (Improvement Factor) = 0.8 for sites > 1 acre or 0.9 for sites ≤ 1 acre

$Q_{1\text{-yr-Developed}}$ = the allowable peak flow rate of runoff from the developed site

$RV_{1\text{-yr-Developed}}$ = the volume of runoff from the site in the developed condition

$Q_{1\text{-yr-Pre-Developed}}$ = the peak flow rate of runoff from the site in the pre-developed condition

$RV_{1\text{-yr-Pre-Developed}}$ = the volume of runoff from the site in pre-developed condition

$Q_{1\text{-yr-Forest}}$ = the peak flow rate of runoff from the site in a forested condition

$RV_{1\text{-yr-Forest}}$ = the volume of runoff from the site in a forested condition

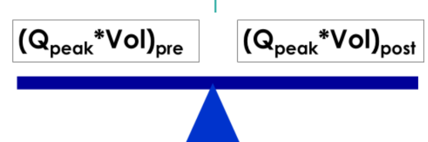
OR

In accordance with another methodology that is demonstrated by the VSMP authority to ***achieve equivalent results and is approved by the board***.

The Energy Balance Method

The Energy Balance Method is intended to achieve a balance between the "energy" exerted on the stream by the pre- and post-developed peak discharge. The formula provided does not actually represent stream energy, but rather a simplification of an effort to balance the hydrologic response characteristics of a developing watershed: impervious cover, channelization, and other impacts associated with the developed landscape result in an increase in the volume and peak rate of runoff. The Energy Balance utilizes the inverse relationship between pre- and post-developed condition runoff volume to reduce the allowable peak discharge:

$$Q_{1post} \leq Q_{1pre} \left(\frac{Pre\ Vol_1}{Post\ Vol_1} \right) (IF)$$



As the post-developed volume ***increases*:**

- the ratio of the Pre to Post volume ***decreases***; and
- the allowable 1-year discharge (Q_{1post}) ***decreases*;** and
- the storage volume required to meet the reduced Q_{1post} ***increases***

Why Energy Balance?

The Energy Balance could have been given any number of different names, and the Energy Balance is a good descriptor. The primary driver of the method comes from two places: First is the Fairfax County "safe harbor" provision that includes the proportional reduction in the allowable peak discharge from a range of design storms.

The second is the mandate from **§ 62.1-44.15:28** of the Code to establish regulations that encourage Low Impact Development (LID). The use of the post development runoff volume (*Post* Vol_1) in the peak discharge formula allows the designer to take credit for the various LID or Environmental Site Design (ESD) strategies that ultimately decrease the post-developed condition ***volume of runoff***.

The designer may elect to reduce impervious cover which is a self-crediting strategy independent of the VRRM: less impervious cover means a lower developed condition Runoff Curve Number (CN). Additional strategies such as minimizing impacts to soils and existing mature vegetation, preserving open space, and implementing non-structural stormwater BMPs are specifically credited within the VRRM and result in less stormwater runoff.

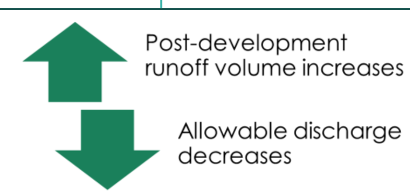
In addition to reducing the post-developed condition volume of runoff (*Post* Vol_1) in the energy balance formula, the reduced curve number as a result of the reduction in impervious cover and the VRRM ***Curve Number Adjustment*** result in a double credit as an incentive to implement ESD strategies.

The Curve Number Adjustment is discussed later in this module.

Revisiting the allowable peak discharge equation above:

$$Q_{1post} \leq Q_{1pre}\left(\frac{Pre\ Vol_1}{Post\ Vol_1}\right)(IF)$$

and reversing the logic in terms of implementing ESD strategies:



Simple "balance" offsets increase in volume and peak flow of developed condition hydrology

As the post-developed volume ***decreases***:

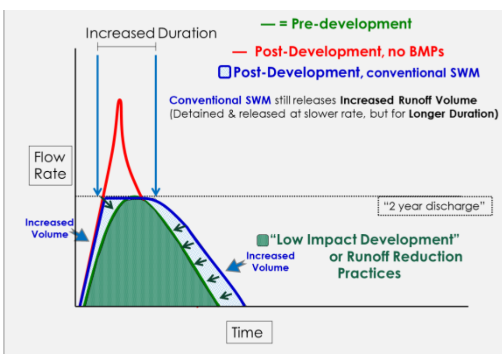
- the ratio of the Pre to Post volume ***increases***; and
- the allowable 1-year discharge (Q_{1post}) ***increases***; and
- the storage volume required to meet the reduced Q_{1post} ***decreases***

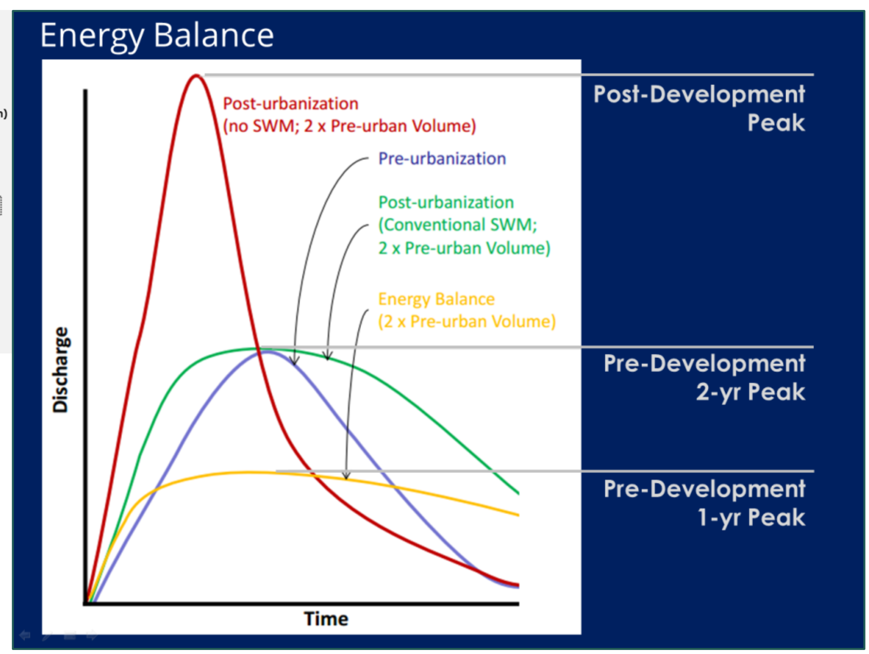
These results provide an incentive for implementing ESD because:

- The strategies can achieve water quality compliance without large land intensive stormwater practices; and
- The use of the VRRM and the Energy Balance Method can decrease (or in some cases even eliminate) the storage volume required for meeting the channel protection criteria

What Is the Improvement Factor?

The Improvement Factor (*IF*) is a statutory hold over from **§ 62.1-44.15:28** that require the stormwater regulations to improve upon the contributing share of the existing predevelopment runoff characteristics and site hydrology if stream channel erosion or localized flooding is an existing predevelopment condition. The Channel Protection criterion for discharges to a Natural Stormwater Conveyance System assumes that the natural channel is not adequate and therefore requires that the Energy Balance Method be used to determine the allowable peak discharge (and storage requirements). It is conceivable that the post developed volume could be ***reduced*** through the use of runoff reduction and ESD strategies that the ratio of Pre Vol1 to Post Vol1 ***increases*** to 1, making the *IF* the basis for "improving upon the existing condition" by a factor of 10% or 20% (equivalent to IF of 0.9 or 0.8, respectively).





Energy Balance Terminology

Both the designer and plan reviewer should become familiar with the terminology of the Energy Balance method as it is documented in the regulations, as well as how various hydrologic methods use the same values with possibly different definitions.

For example, the most common symbol in stormwater management documentation is that of runoff peak discharge, **Q**, measured in cubic feet per second. However, the NRCS Technical Release 55 (TR-55), the foundational document for computing urban runoff using NRCS methods, designates the same runoff peak discharge, measured in the same units of cubic feet per second, with a lower case **q**. To keep things interesting, TR-55 designates the depth of runoff measured in watershed inches as upper case **Q**.

Another important value that can be the cause of possible confusion is the use of **RV** as the symbol for Runoff Volume in the Energy Balance equation as published in the regulations and noted above. (Notice that the rearranged Energy Balance equation version substitutes these values with **Pre** $\mathbf{Vol_1}$.) The VRRM Compliance spreadsheet uses the term **RV** to refer to runoff depth in inches, which can be used in the Energy Balance equation in place of the runoff volume.

Table 5-1 provides a summary of the different terms used by the different published sources, along with the corresponding units. There is no absolute right or wrong version of the units, as long as they are used consistently within the design.

Table 14-1 Hydrology Terminology

Description	Units	Term
NRCS TR-55		
Runoff Depth	inches (in)	***Q***
Runoff Volume	cubic feet (ft^3) or acre feet (ac.ft.)	***Vr***
Storage Volume	cubic feet (ft^3) or acre feet (ac.ft.)	***Vs***
Peak Discharge	cubic feet per second (cfs)	q_p
VRRM Treatment Volume Runoff Coefficients		
Unit-less Volumetric Runoff Coefficients		***Rv***
VRRM Curve Number Adjustment		
Runoff Depth	inches	***RV***
VSMP Regulations Channel Protection Criteria (4VAC50-60-66.B)		
Peak Discharge	cubic feet per second (cfs)	***Q***
Runoff Volume*	cubic feet (ft^3) or acre feet (ac.ft.)*	***RV***
*Units of volume in the VSMP regulations Channel Protection Criteria can also be expressed in terms of *watershed-inches* or inches (consistent with Runoff Depth as expressed in the VRRM *CN* adjustment.		

Considering the nomenclature distinction provided in Table 14-1, the Energy Balance Equation:

$$Q_{1post} \leq Q_{1pre} \left(\frac{RV_{pre1}}{RV_{post1}} \right) (IF)$$

can be re-written as:

$$q_{1post} \leq q_{1pre} \left(\frac{Vr_{pre1}}{Vr_{post1}} \right) (IF)$$

14b. Energy Balance Design Example

The benefit of the Energy Balance is the credit provided for using ESD and RR practices to reduce the runoff volume and achieve a CN Adjustment. In principle, when ESD and runoff reduction practices are used to capture and retain or infiltrate runoff, downstream stormwater management practices should not have to detain, retain or otherwise treat the volume that has been previously removed. In other words, the volume of runoff reduction should be removed from the volume computations for Energy Balance and Channel Protection compliance. The challenge lies in how to accurately credit the *annual* volume reduction when performing *single-event* computations of peak discharge and detention storage from larger storms.

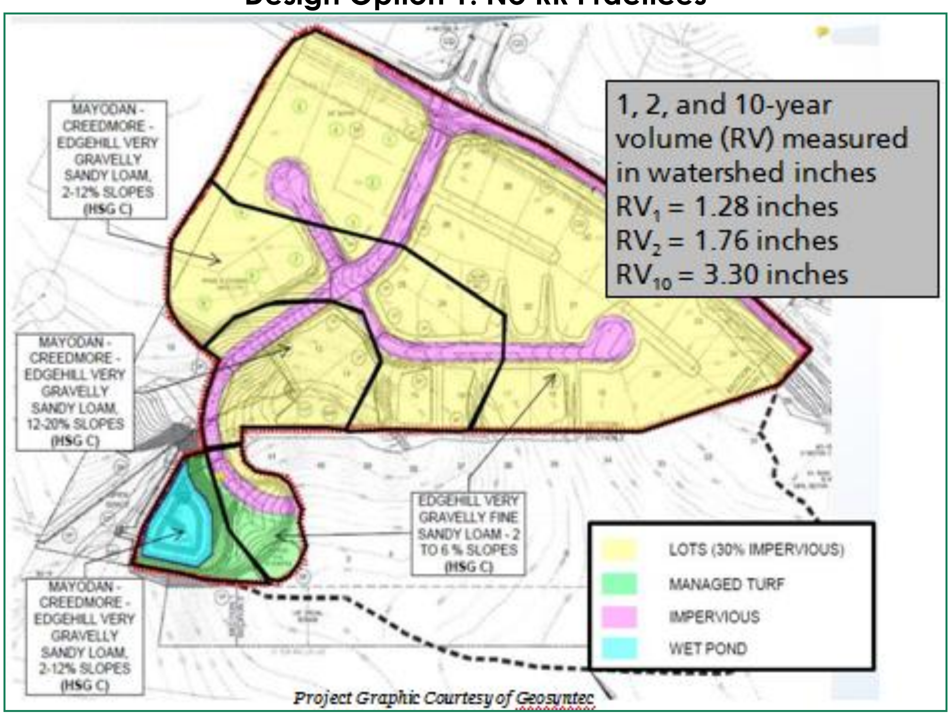
The following Design Example illustrates the Energy Balance method starting with the Curve Number adjustment.

Compliance Spreadsheet CN Adjustment

The CN Adjustment computations start with determining CN and computing the corresponding runoff depth.

Consider design option 1 – no RR Practices: **CN = 83** and the corresponding 1-year runoff volume (or depth measured as watershed inches, RV_1) as shown.

Design Option 1: No RR Practices



Review Question: Where does the depth of runoff (RV_1) come from?

Calculate using **TR-55 Runoff Equations 2-3 and 2-4** (refer back to Module10):

$$S = \frac{1000}{CN} - 10 \quad = \frac{1000}{83} - 10 \quad = 2.05$$

(Source: TR-55, Eq. 2-4)

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \quad = \frac{\left(2.79 - (0.2 \times 2.05)\right)^2}{\left(2.79 + (0.8 \times 2.05)\right)}$$

(Simplified Runoff Equation. Source: TR-55, Eq. 2-3)

$$Q = 1.28 \text{ inches}$$

(RV is synonymous with Q in the TR-55 Runoff Equations)

OR

Read from **TR-55 Figure 2-1: Solution of Runoff Equation**

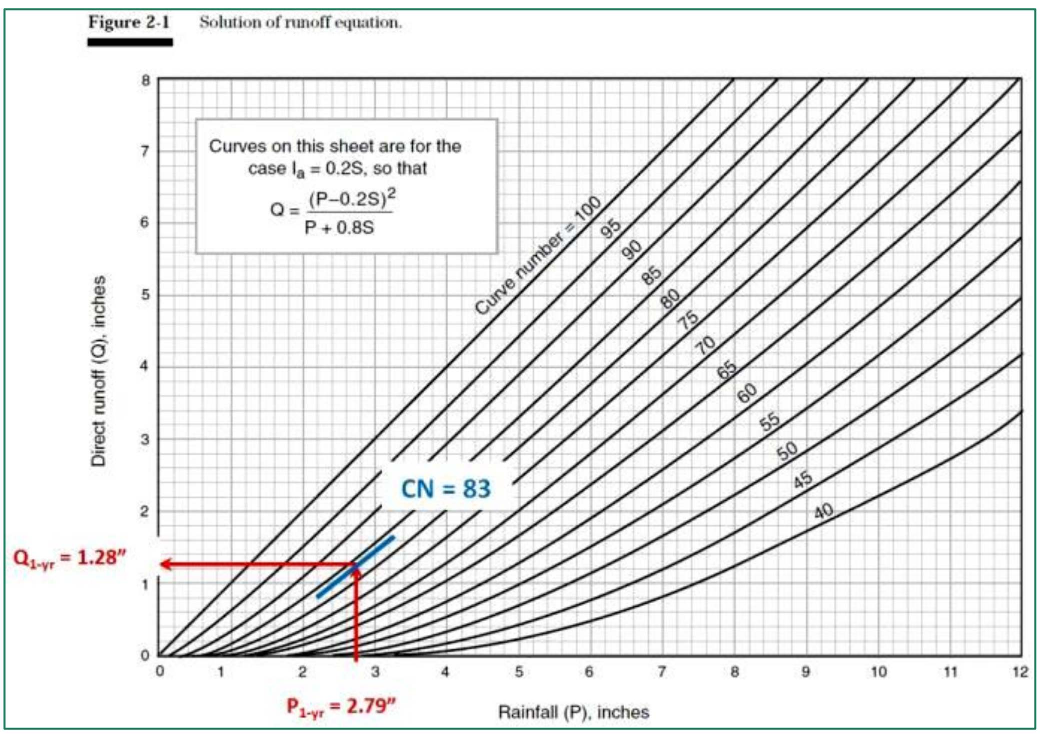
OR

Interpolate from **TR-55 Table 2-1: Runoff Depth for Selected CN's and Rainfall Amounts**

OR

Use WIN-TR-55 or any NRCS based stormwater hydrology software.

TR-55 Figure 2-1



TR-55 Table 2-1

Table 2-1 Runoff depth for selected CN's and rainfall amounts 1/

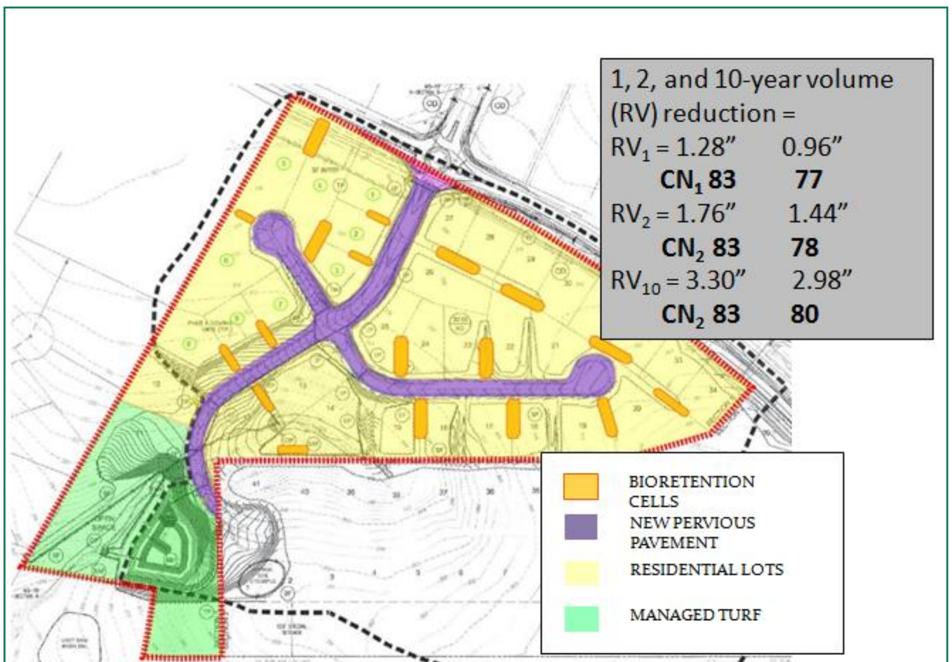
Rainfall	Runoff depth for curve number of— CN = 83												
	40	45	50	55	60	65	70	75	80	85	90	95	98
	inches												
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.17	0.32	0.56	0.79
1.2	.00	.00	.00	.00	.00	.00	.03	.07	.15	.27	.46	.74	.99
1.4	.00	.00	.00	.00	.00	.02	.06	.13	.24	.39	.61	.92	1.18
1.6	.00	.00	.00	.00	.01	.05	.11	.20	.34	.52	.76	1.11	1.38
1.8	.00	.00	.00	.00	.03	.09	.17	.29	.44	.65	.93	1.29	1.58
2.0	.00	.00	.00	.02	.06	.14	.24	.38	.56	.80	1.09	1.48	1.77
2.5	.00	.00	.02	.08	.17	.30	.46	.65	.89	1.18	1.53	1.96	2.27
3.0	.00	.02	.09	.19	.33	.51	.71	.96	1.25	1.59	1.98	2.45	2.77
3.5	.02	.08	.20	.35	.53	.75	1.01	1.30	[illegible]	[illegible]	2.45	2.94	3.27
4.0	.06	.18	.33	.53	.76	1.03	1.33	1.67	[illegible]	[illegible]	2.92	3.43	3.77
4.5	.14	.30	.50	.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92	4.26
5.0	.24	.44	.69	.98	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.42	4.76
6.0	.50	.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.30	4.85	5.41	5.76
7.0	.84	1.24	1.68	2.12	2.60	3.10	3.62	4.15	4.69	5.25	5.82	6.41	6.76
8.0	1.25	1.74	2.25	2.78	3.33	3.89	4.46	5.04	5.63	6.21	6.81	7.40	7.76
9.0	1.71	2.29	2.88	3.49	4.10	4.72	5.33	5.95	6.57	7.18	7.79	8.40	8.76
10.0	2.23	2.89	3.56	4.23	4.90	5.56	6.22	6.88	7.52	8.16	8.78	9.40	9.76
11.0	2.78	3.52	4.26	5.00	5.72	6.43	7.13	7.81	8.48	9.13	9.77	10.39	10.76
12.0	3.38	4.19	5.00	5.79	6.56	7.32	8.05	8.76	9.45	10.11	10.76	11.39	11.76
13.0	4.00	4.89	5.76	6.61	7.42	8.21	8.98	9.71	10.42	11.10	11.76	12.39	12.76
14.0	4.65	5.62	6.55	7.44	8.30	9.12	9.91	10.67	11.39	12.08	12.75	13.39	13.76
15.0	5.33	6.36	7.35	8.29	9.19	10.04	10.85	11.63	12.37	13.07	13.74	14.39	14.76

$P_{1\text{-}yr}$ = 2.79″ — 1.28″

1/ Interpolate the values shown to obtain runoff depths for CN's or rainfall amounts not shown.

Consider design option 2 – with RR Practices: **CN $_1$ = 83** and 1-year runoff volume (or depth measured as watershed inches, RV_1) as shown, and a CN adjustment to **CN_1 = 77** corresponding to a reduced **RV_1 = 0.96″**.

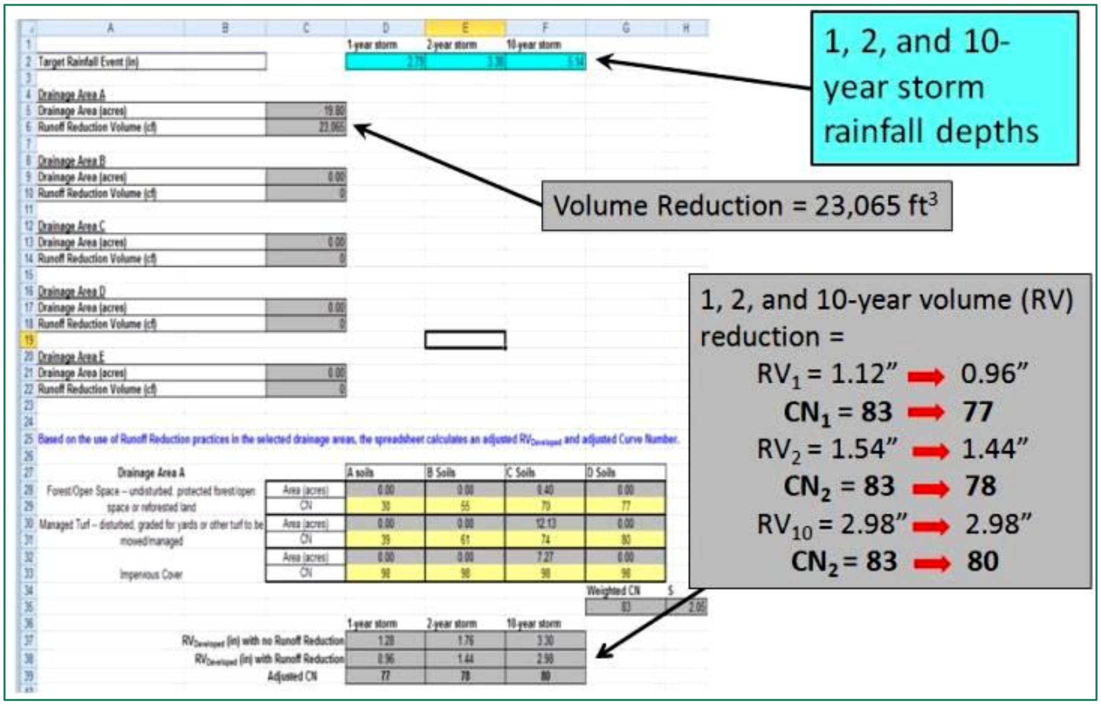
Design Option 2: With RR Practices



Project Graphic Courtesy of Geosyntec

Question: How does the RV_1 drop from 1.28" to 0.96"? And how does the CN_1 drop from 83 to 77?

Easy Answer: VRRM Compliance Spreadsheet Channel & Flood Protection Tab **CN Adjustment**



Complicated Answer: Use the NRCS Runoff Equations to back calculate an adjusted CN that reflects the retention storage of the credited RR Practices.

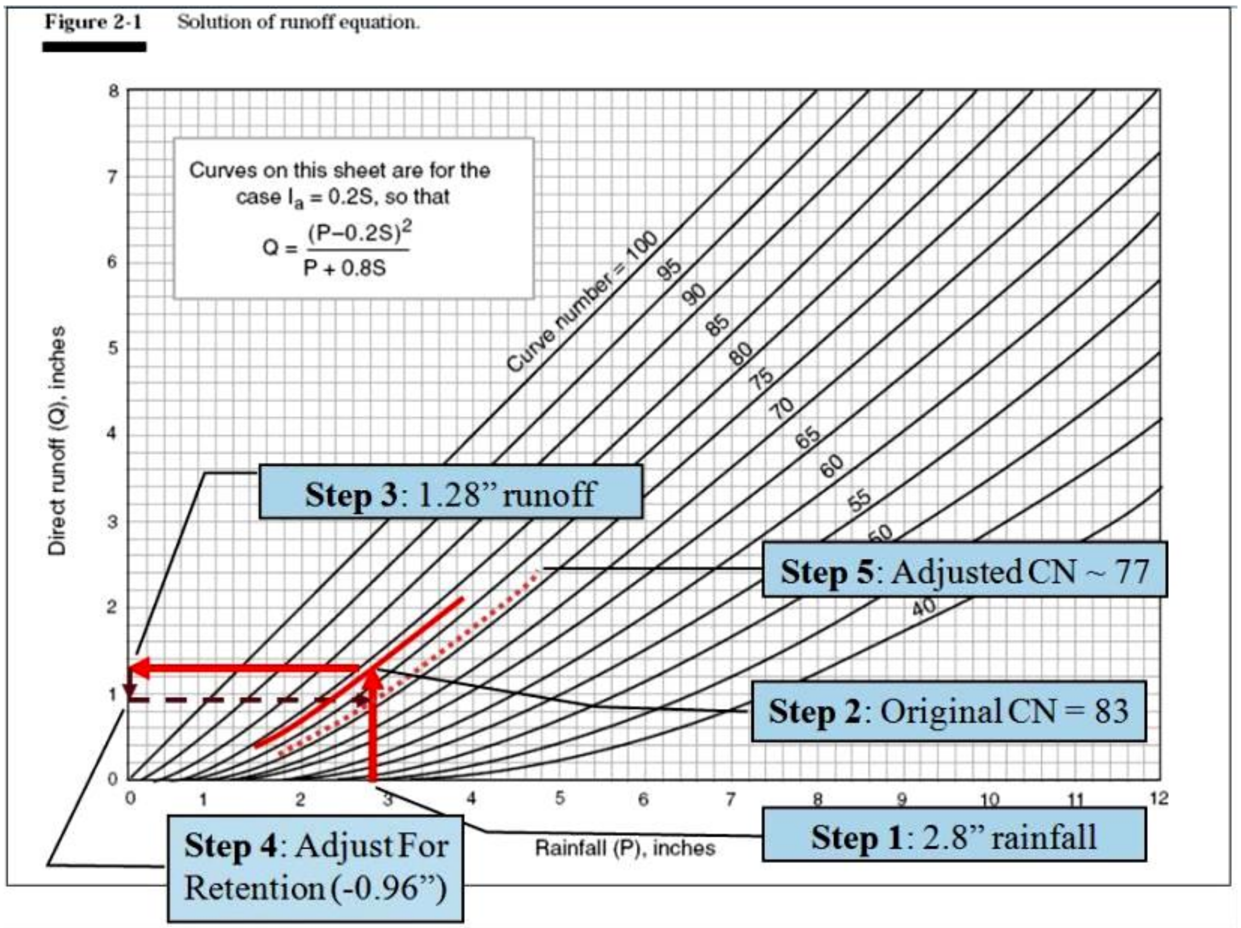
The mandate from **§ 62.1-44.15:28** of the Code to establish regulations that encourage Low Impact Development (LID) created a challenge to accurately documenting the benefits posed by reducing stormwater runoff with multiple decentralized stormwater practices. The objectives included:

- Provide quantity "credit" for distributed retention practices;
- Avoid Complex routing/modeling of multiple practices, yet simulate single event modeling;
- Allow designers to target volume as a primary metric (quantity and quality);

Some simplifying assumptions were allowed:

- Assume retention is uniformly distributed if considering multiple (decentralized) features or sub-areas;
- Assume negligible discharge from under-drains (if any).

A graphical representation of how the curve number adjustment for the example provided above can be graphically solved is provided below:



Back to the Design Example Option 2: with RR

The back-calculated adjusted CN based on the site (or drainage area) RR is shown in the figure below. The water quality compliance has been verified in the VRRM Compliance spreadsheet Water Quality Compliance tab, and the Channel & Flood Protection tab provides the corresponding CN adjustment.

Energy Balance Computation of Allowable One-year Discharge (Q_{1post})

The pre- and post-developed condition hydrology and peak discharge is required in order to complete the Energy Balance computation. **Table 14-2** provides a summary of the Channel & Flood Protection tab information, and includes the (previously computed) pre- and post-developed peak discharge.

Channel & Flood Protection Tab of the VRRM Compliance Spreadsheet

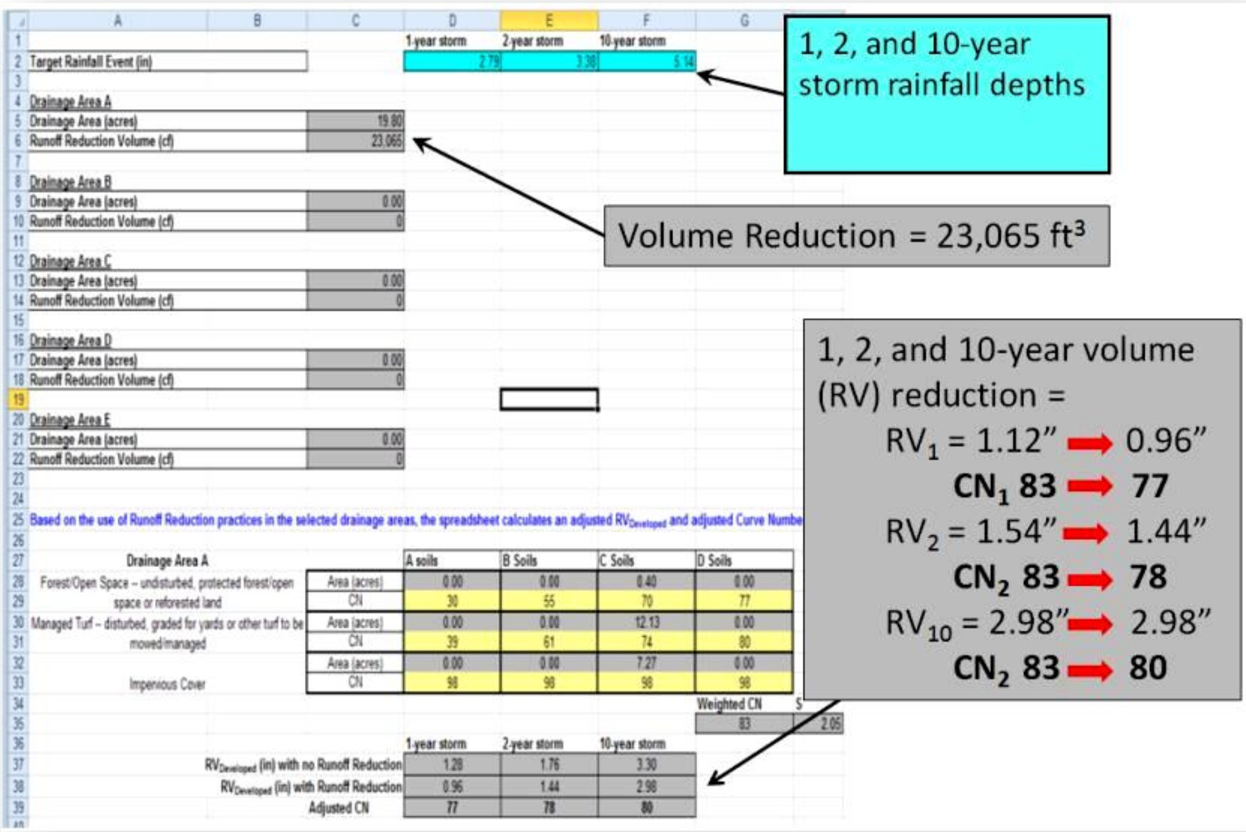


Table 14-2. 1-year Storm Channel & Flood Protection Tab Data Summary and Peak Discharge

One-Year Storm Hydrology Summary: 19.8 acres			
	Pre-Developed	Post-Developed no RR	Post-Developed with RR
Runoff Curve Number	71	83	77
Runoff Volume (RV)	0.62 in	1.28 in	0.96 in
Runoff Volume	1.02 ac-ft.	2.11 ac-ft.	1.58 ac-ft.
Peak Discharge (q_1)	9 cfs	39 cfs	27 cfs
Post Developed EB Allowed Peak Discharge (cfs)			
Storage Volume Reqd., (ac-ft)			

The pre-developed peak discharge of 9 cfs is the q_{1pre} in the Energy Balance equation:

$$q_{1post} \leq q_{1pre}\left(\frac{Vr_{pre1}}{Vr_{post1}}\right)(IF)$$

In order to compare the benefit of implementing ESD and/or RR practices, the Energy Balance and the volume of storage required will be computed reflecting both design options: with, and without RR.

Without RR:	**With RR**
$q_{1post} \leq q_{1pre}\left(\frac{Vr_{pre1}}{Vr_{post1}}\right)(IF)$	$q_{1post} \leq q_{1pre}\left(\frac{Vr_{pre1}}{Vr_{post1}}\right)(IF)$
$q_{1post} \leq 9\ cfs\left(\frac{0.62"}{1.28"}\right)(0.8)$	$q_{1post} \leq 9\ cfs\left(\frac{0.62"}{0.96"}\right)(0.8)$
$q_{1post} \leq \mathbf{3.5\ cfs}$	$q_{1post} \leq \mathbf{4.7\ cfs}$

Note that the allowable peak discharge increases with the implementation of runoff reduction.

Also, as noted in **9VAC25-870-66**:

Under no condition shall q_{1post} be greater than q_{1pre} (i.e., the ratio of Vr_{pre1} to Vr_{post1} cannot be increased through ESD or RR practices to be greater than 1.25);

nor shall q_{1post} be required to be less than that calculated in the equation:

$$q_{1forest}\left(RV_{1forest}/RV_{1post}\right)$$

*Note: Remember that the **runoff volume** is **Vr** in TR-55 nomenclature and **RV** in the VRRM.*

Table 14-3. 1-year Storm Channel & Flood Protection Tab Data Summary & Peak Discharge

One-Year Storm Hydrology Summary: 19.8 acres			
	Pre-Developed	Post-Developed no RR	Post-Developed with RR
Runoff Curve Number	71	83	77
Runoff Volume (RV)	0.62 in	1.28 in	0.96 in
Runoff Volume	1.02 ac-ft.	2.11 ac-ft.	1.58 ac-ft.
Peak Discharge (q_1)	9 cfs	39 cfs	27 cfs
Post Developed EB Allowed Peak Discharge (cfs)		**3.5 cfs***	**4.7 cfs***
Storage Volume Reqd., (ac-ft)			

Note the double benefit of the VRRM: the peak discharge ($\boldsymbol{q_1}$) is reduced, and the allowable peak discharge ($\boldsymbol{q_o}$) is increased

The designer can calculate the storage volume required with the developed condition peak inflow (qi) and the allowable peak discharge or outflow (qo). Typically this will involve the use of computer based Storage Indication or level pool routing software (or can be calculated using a pencil and paper with the storage indication routing instructions found in the Blue Book).

Another option is the use of TR-55's Figure 6-1. This plot provides an estimate of the level pool routing continuity equation: ***Inflow – Outflow = ds/dt*** (the change in storage over time) based on the design hydrology: the allowable peak outflow ($\boldsymbol{q_o}$), peak inflow ($\boldsymbol{q_i}$), and the volume of runoff ($\boldsymbol{V_r}$ or $\boldsymbol{RV_{post}}$). The method then solves for the required storage ($\boldsymbol{V_s}$).

The method provides an estimate and may be useful for quickly evaluating different design options or reviewing plans. However, the method should only be used for final design if a 25% margin of error is acceptable.

Table 14-4. 1-year Storm Channel & Flood Protection Tab Data Summary and Storage Required

One-Year Storm Hydrology Summary: 19.8 acres			
	Pre-Developed	Post-Developed no RR	Post-Developed with RR
Runoff Curve Number	71	83	77
Runoff Volume (RV)	0.62 in	1.28 in	0.96 in
Runoff Volume	1.02 ac-ft.	2.11 ac-ft.	1.58 ac-ft.
Peak Discharge (q_1)	9 cfs	39 cfs	27 cfs
Post Developed EB Allowed Peak Discharge (cfs)		**3.5 cfs**	**4.7 cfs**
Storage Volume Reqd., (ac-ft)		**1.16 ac-ft.***	**0.76 ac-ft.***

The implementation of ESD and RR Practices results in a 37% reduction in 1-year storm Energy Balance storage requirement.

VRRM Compliance Spreadsheet Limitations

The VRRM Compliance Spreadsheet is just that: a compliance spreadsheet. It allows the designer to quickly evaluate the performance of different ESD strategies and combinations of RR practices BMP, and plan reviewers to quickly evaluate the compliance of those strategies and practices. Designers will still need to design the practices, e.g. identifying that a Wet Pond Level 2 provides for compliance as documented with the VRRM Compliance spread does not design the practice. This topic is further explored in the DEQ Plan Reviewer for Stormwater Management Certification course.

14c. Flood Protection

Flood Protection criteria are based on an assessment of the current condition of the downstream *Stormwater Conveyance System*: Does it currently experience localized flooding during the ***10-year 24-hour storm event***?

9VAC25-870-66.C: Flood Protection:

1. Discharges to areas that are ***not experiencing localized flooding*** must ensure that the post-development peak flow rate from the 10-year 24-hour storm event is confined within the stormwater conveyance system. Detention of stormwater or downstream improvements may be incorporated into the approved land-disturbing activity to meet this criterion, at the discretion of the VSMP authority.

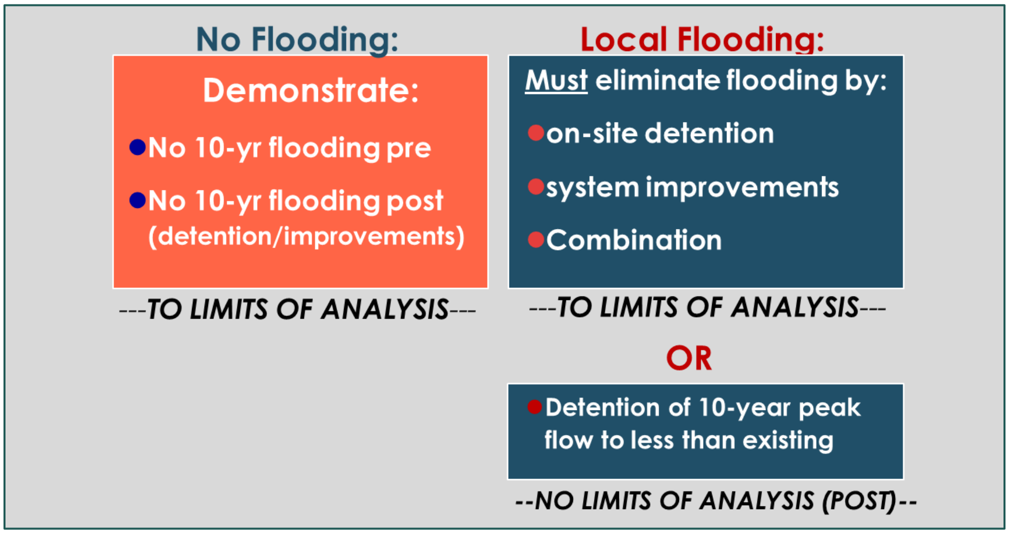
2. Discharges to areas that are ***experiencing localized flooding*** must:

    a. Confine the post-development peak flow rate from the 10-year 24-hour storm event within the stormwater conveyance system to avoid the localized flooding. Detention of stormwater or downstream improvements may be incorporated into the approved land-disturbing activity to meet this criterion, at the discretion of the VSMP authority; or

    b. Releases a post-development peak flow rate for the 10-year 24-hour storm event that is less than the predevelopment peak flow rate from the 10-year 24-hour storm event. Downstream stormwater conveyance systems do not require any additional analysis to show compliance with flood protection criteria if this option is utilized.

Localized flooding is defined in the regulations as smaller scale flooding that may occur outside of a stormwater conveyance system, which may include high water, ponding, or standing water from stormwater runoff, which is likely to cause property damage or unsafe conditions. Since this definition may lead to subjective determinations of the presence (or lack of) localized flooding, the VSMP Authority may identify areas to be subject to item 2.

In all cases, compliance with the requirement to keep the 10-year 24-hour peak flow rate confined within the downstream stormwater conveyance system includes an allowance for VSMP Authority discretion in allowing or excluding either on site detention or downstream channel improvements as an option for demonstrating compliance.



Limits of Analysis for Flood Protection

9VAC25-870-66

Downstream conveyance system analysis is applicable in the flood protection criteria when the existing downstream Stormwater Conveyance System:

- Does not experience localized flooding and the system will contain the post-development peak discharge as required, where on-site detention and/or downstream improvements can be implemented in order to alleviate the localized flooding (at VSMP authority discretion); or
- Does experience localized flooding and the system will contain the post-development peak discharge as required to avoid localized flooding, where on-site detention and/or downstream improvements can be implemented in order to alleviate the localized flooding (at VSMP authority discretion).

The designer must analyze the stormwater conveyance system using ***acceptable hydrologic and hydraulic methodologies*** to the defined limit of analysis.

The limit of analysis is a function of the site's contributing drainage area as follows:

a. The site's contributing drainage area is less than or equal to 1.0% of the total watershed area draining to a point of analysis in the downstream stormwater conveyance system; or

b. Based on peak flow rate, the site's peak flow rate from the 10-year 24-hour storm event is less than or equal to 1.0% of the existing peak flow rate from the 10-year 24-hour storm event prior to the implementation of any stormwater quantity control measures; or

c. The stormwater conveyance system enters a mapped floodplain or other flood-prone area, adopted by ordinance, of any locality.

14d. Sheet Flow

Sheet flow is addressed in Part IIB of the SWM regulations (9VAC25-870-66.D):

9VAC25-870-66: Water Quantity:

> D. Increased volumes of sheet flow resulting from pervious or disconnected impervious areas, or from physical spreading of concentrated flow through level spreaders, must be identified and evaluated for potential impacts on down-gradient properties or resources.

Notes

Module 14 Work Problems