DCR Stormwater Management Regulation Revision Process
Water Quantity Control Criteria Workgroup
Tuesday, April 22, 2008 – 1:00 p.m.
Patrick Henry Building
Richmond, Virginia

MINUTES

Water Quantity Control Criteria Workgroup Members Present

Joe Battiata, Contech
Doug Beisch, Williamsburg Environmental Group
Michelle Brickner, Fairfax County
Darryl Cook, James City County
Jeff Cowan, Dewberry & HBAV
Scott Crafton, DCR
Dr. Joanna Curran, UVA
Glenn Curtis, Draper Aden & ASCE
Mike Gerel, Chesapeake Bay Foundation
Lee Hill, DCR
Steve Kindy, VDOT
Ved Malhotra, P.E.
John Matusik, The Engineering Group & ESI
Fernando Pasquel, Baker Engineering
Michael Rolband, Wetland Studies & Solutions
Ridge Schuyler, The Nature Conservancy
John Tippett, Friends of the Rappahannock
Keith White, Henrico County

Water Quantity Control Criteria Workgroup Members Not Present

Randy Bartlett, Fairfax County
Glen Brooks, Albemarle County
David Crawford, Cabell Brand Center
Roy Mills, VDOT
Joe Modica, Kimly Horn & TBA
Pete Rigby, Paccuilli, Simmons & NVBIA
Dan Sweet, VHB

DCR Staff Present

Robert Bennett
Ryan Brown
Eric Capps
Chuck Deitz
David Dowling
Pam Landrum
John McCutcheon
Christine Watlington

Others Present

Elizabeth Andrews, Office of the Attorney General
David Powers, Baker
Norm Goulet, NVRC
David Hirschman, CWP
Barrett Hardiman, HBAV

<u>Call to Order</u>

Mr. Crafton called the meeting to order at 1:00 p.m. and thanked everyone for coming. He indicated that this workgroup was formed because of a recommendation from the DCR's Stormwater management Regulation Technical Advisory Committee (TAC) to more specifically address the water quantity control requirements in the regulations. Mr. Crafton called attention to the meeting agenda **(Handout 1/Attachment 1)**.

Mr. Crafton commented that today's meeting is an introductory meeting and intended to establish a context for the quantity discussions. For those who have not been involved in the TAC or the site plan workshops, there will be a brief review about what's happening on the water quality side. We will go through the different kinds of quantity criteria that stormwater managers deal with and how they work together; and lay the groundwork and explain, to the degree that Virginia has criteria related to those topic areas, what they are and where we might be headed.

Mr. Crafton reviewed the background and what led to the development of this workgroup.

- DCR filed a Notice Of Intended Regulatory Action (NOIRA) to revise stormwater management regulations in the fall of 2005
- A regulation revision Technical Advisory Committee (TAC) was formed 2006
- Last fall, DCR was asked to withdraw the NORIA and republish it, providing more clarity regarding what changes are intended; the new NOIRA was filed in October, 2007 and approved by the Administration in February of this year. Public Comment on the NOIRA was taken between March 16 and April 16. The regulatory TAC is now being formed again.
- Up to last September, the main focuses have been on updating administrative oversight and program administration criteria (Part III); updating the water quality and quantity criteria, to include addressing the nutrient reduction goals of the Chesapeake Bay Program (Part II); and updating the permit fee schedule to reasonably reflect the state and local workload involved with administering the program (Part XIII).
- The TAC recommended giving more attention to the water quantity control criteria. Language in the Stormwater Management (SWM) and Erosion and Sediment (E&S) Control Regulations need to be consistent and supportive, in particular because channel protection criteria relate to management standard 19 under the erosion control regulations. That's the criteria that have tended to drive channel protection in Virginia and is the foundation criteria. The language that shows up in the stormwater regulations is basically copied from the E&S law and regulations.

Mr. Crafton indicated that DCR believes it is more appropriate to actually make improvements in the water quantity criteria and include it in the stormwater regulations and law, and then later refer the E&S standards back to stormwater regulations. Water quality and quantity are stormwater issues and we are making the effort to address the issues, make whatever improvements are needed, and include all of them in the stormwater regulations. Then MS19, in its current form, will probably drop out of the E&S regulations and there will be some reference that points to the stormwater regulations.

Mr. Crafton commented that some TAC members have also asked DCR to consider adding requirements in the regulations that specifically address groundwater recharge and runoff volume reduction.

DCR SWM/E&S "Quantity Control" Criteria Discussion

Mr. Crafton reviewed the five aspects of stormwater quantity that the workgroup will try to address: **(Handout 2/Attachment 2)**

Groundwater recharge or runoff volume reduction

Groundwater recharge control tends to aim at storms that are very small and that tend not to generate runoff. Currently in the regulations there is no requirement to address recharge or runoff volume. The new Runoff Reduction Methodology, developed for DCR by the Center for Watershed Protection (CWP), more effectively accomplishes water quality protection, focusing to a large degree on runoff volume reduction as the critical mechanism for pollution removal. Under this approach, DCR is addressing runoff volume reduction through the compliance process rather than as a stated regulatory requirement. Once work group members understand this methodology, then we need to consider whether this approach is sufficient to address runoff volume and, by extension, groundwater recharge or, alternatively, whether DCR should still consider adding specific recharge or runoff volume reduction requirements to the regulation. Some states have developed design criteria to promote recharge and/or runoff volume reduction at development sites. These are listed in **Table 1 of Attachment 2**.

Water quality protection

The water quality requirements in the current regulations focus on treating the "first flush" of runoff, which is typically the first ½-inch of runoff. The proposed regulations and the Runoff Reduction Methodology that DCR is proposing to use aim at treating the runoff from a one-inch rainfall event. If you graph rainfall events in Virginia and the Chesapeake Bay region, measuring the amount of rainfall, the one-inch rainfall event tends to be at the 90^{th} percentile of rainstorms. That means that 90 percent of the storms that occur in this region tend to have one inch or less of rainfall. **(Handout 3/Attachment 3)**This is something that stormwater scientists and engineers have encouraging to optimize our standards, so we are not over-sizing BMPs and spending a lot of money to control rainfall quantities that rarely occur.

The methodology that the CWP has proposed categorizes all the different BMP's into levels. Level 1 practices aim at median pollution removal rates for phosphorus, based on the national pollution reduction performance database. Their recommended sizing for those BMPs is aimed at treating the runoff from the 1-inch rainfall. There are Level 2 versions of each of the BMP's that aim at achieving the removals at the 75^{th} percentile. The level 2 BMPs, depending on which practice it is, are sized at some multiple of the 1-inch storm. So, the best current science instructs us that we should aim at controlling the runoff from the 1-inch rainfall event for our water quality criteria.

Stream channel protection

Currently the stream channel protection performance requirement is addressed in the E&S control law and regulations and is embodied in Minimum Management Standard 19 (MS-19). There is also language in the stormwater regulations that reflects what is in the E&S law. MS-19 requires the protection of downstream properties and streams from sediment deposition, erosion and other runoff related damage due to quantity, volume, velocity, peak flow, etc.

A key to MS19, as it is currently written, is that the person being regulated must assure that there is an adequate receiving channel downstream from the development site. There has been a lot discussion interchanging the terms "adequate channel" versus "adequate outfall." For this exercise, we will refer to the language in the regulations, which refers to "adequate channel." Up to now, to assure the receiving channel is adequate and protect it from channel erosion, the regulations require detention of the post development two-year/24-hour storm and releasing the flow at the rate of the pre-development two-year/24-hour storm. There is room for much discussion about whether this is the best way to provide stream channel protection. As a point of discussion, Dave Hirschman of the CWP has provided a handout of suggested *"Stable Environmental Conveyance Criteria"* **(Handout 4/Attachment 4)**

The CWP has suggested that instead of using the two-year/24-hour storm, we focus on the detaining the one-year/24-hour storm and releasing the flow over a 24-hour period. That is actually included now in the language of the stormwater law and regulations, as one of several options, and several Virginia communities have adopted this approach.

Some stormwater experts now suspect that controlling the one-year/24-hour storm for channel protection purposes may result in building BMPs that are larger than they need to be to adequately protect receiving channels. Therefore, determining the appropriate design storm for channel protection purposes is going to be one of the most important issues that this workgroup needs to resolve.

Another of the handouts that you were provided is essentially the text of the channel protection language in both the SWM law and regulations and the E&S law and regulations **(Handout 5/Attachment 5)**. There is a lot of text involved in those four different citations dealing with this issue. What we hope to do is (1) simplify and filter the language to make it consistent with the key principals that we have now, (2) make it reasonably easy to understand, (3) develop criteria that avoids having designers playing math games with plan reviewers, (4) provide accountability regarding compliance in achieving the goal of adequate protection of downstream properties and resources, and (5) have criteria that will integrate well with the methodology to address water quality protection. That's a lot, and it will not be easy to accomplish, especially in the short time we have. However, DCR believes we have the right people in this work group to help us do these things.

Overbank flood protection

Currently, DCR requires the control of a post-development 10-year/24-hour storm back to the pre-development 10-year storm release rate. This requirement is aimed at trying to prevent minor flooding events to be sure any constructed channels on our sites can actually convey the 10-year post-development flow without overtopping their banks. At this point DCR does not expect to change this criteria, since it is widely accepted and used for this purpose.

Committee members expressed concern over confusion regarding the adaptation of the criteria. There were particular questions about whether this requirement needs to apply at all sites or, instead, should be required only under specific conditions. Mr. Crafton indicated that this is an issue the work group should discuss and resolve.

Extreme flood protection

This is generally addressed by separate federal and local flood plain regulations and ordinances. However, BMP's have to be designed to safely bypass the post-development 100-year storm in a manner that protects the structural integrity of the practices. Again, this is not something that DCR expects to change, unless the work group has significant concerns about the current procedures.

<u>Identified Goals of the Work Group:</u>

- Recommending what to do in the SWM regulations about recharge and/or runoff volume reduction;
- Recommending what to do in the SWM regulations about the channel protection criteria; and
- If possible, recommending how to best account for the effect of distributed runoff reduction practices on storm flow routings and resulting runoff hydrographs for the site **(Handouts 6, & 7/Attachments 6 – see DCR web site regulatory page for Handout 7 as PDF)**.

Mr. Crafton stated that there has been discussion on the change in rainfall frequency and intensity patterns as the climate changes. He said if we look at the rainfall frequency and intensity patterns over the last 100 years, the rainfall charts that are currently used make sense. But if we look at them for just the past 30 years, the patterns appear to have significantly changed. One suggestion is to make sure that engineers are designing with the best and most current rainfall charts. Several members recommended the new rainfall records reflected in NOAA's new *Atlas 14* publication as the most recent updates of the long-term rainfall data. They cautioned that there is still no broad agreement that using a shorter time-period to further revise this criterion is scientifically defensible.

Mr. Crafton suggested that rather than trying to deal with this issue as an independent agency, there has been discussion about establishing a stormwater summit in the Chesapeake Bay Region, later this year, to bring all the state program administrators together to discuss what we are doing and to try to get everyone moving in the same direction and essentially adopting very similar, if not identical, criteria. It is thought that this would be the optimal place to raise the issue of the effects of climate change on the rainfall charts. Such a group could approach NOAA collectively about reevaluating the rainfall records in light of more recent climate change trends and, perhaps, establishing a further update of the records.

<u>Runoff Reduction Methodology</u>

Mr. David Hirschman, of the Center for Watershed Protection (CWP), highlighted the work that has been done with DCR in drafting the Runoff Reduction Methodology. **(Attachment 8)** He noted that this method has been developed both to assist DCR with its SWM regulation revision, but also as a key method for use by early adopter communities in a CWP project called the *Extreme BMP Makeover Project*, which involves approximately a half-dozen communities in the James River basin of Virginia. The runoff reduction method being proposed is a three step process, which is different from what is being done now with the pollutant removal rates. The process focuses on:

- Post development land cover
- Runoff volume reduction practices
- Pollutant removal (treatment) practices

Mr. Hirschman reviewed with the committee the nine runoff reduction practices:

- Drainage to open space
- Rooftop disconnection
- Pervious parking
- Green roof
- Grass channels
- Bio-retention dry swale
- Wet swale
- Infiltration
- Extended detention

He stated that each practice is assigned a runoff reduction rate. Based on the post-development land cover, there is certain treatment volume that is generated that you would be responsible for, in order to meet water quality requirements. He commented that with the current system it has been challenging to establish compliance, and there have been discussions on whether you can bypass the runoff reduction and go directly to pollutant removal. The outcome in recently conducted DCR Site Plan Charette Workshops has been that many people have had to use all three steps to achieve compliance for their assigned site plans.

Mr. Hirschman indicated that ten objectives of integration were developed to assist stormwater managers and site designers. He stressed the importance for the workgroup to discuss the objectives and to clarify why and if the workgroup feels that all ten of the objectives are important.

- Field performance – solves real problems;

- More efficiency – doesn't lead to overbuilding of BMPs;
- Incentives for runoff reduction and better site designs;
- Simple – easy to understand and use;
- Allows a range of practices – broadens the suite of BMPs to use at a site;
- Accountability for the local Public Works staff – so that today's plan approvals do not result in tomorrow's drainage complaints;
- Defensible – makes sense, is realistic and plausible;
- Accurate – reflects the actual site hydrology;
- Adaptable to different pollutants – can address pollutants of concern for different applications;
- Relevant at the sub-watershed level – can be tied to stormwater benchmarks for the sub-watershed, such as flow, volume, and pollution load reduction.

Mr. Hirschman stated that one big challenge facing stormwater mangers and site designers is developing an adequate hydrograph-generating technique. He discussed another CWP handout **(Handout 6/Attachment 6)** briefly reviewed several different approaches and methods identified by the CWP:

- Truncated Hydrograph (volume diversion)
- Hydrograph Scalar Multiplication
- Precipitation Adjustment – subtract retention from rainfall
- Adjusted CN (curve number)
- Runoff Adjustment – Subtract retention from runoff

Mr. Hirschman stated of the methods listed above, Runoff adjustment – subtract retention from runoff – is the preferred method. The CWP considers the second best choice to be the Adjusted Curve number method. There was some general discussion of this by work group members.

General Workgroup Discussion

The Committee had a general discussion on the methodology currently being used and identified some of the areas that need the committee's attention:

- Who determines what is practicable – define thresholds
- Detention time (one-year/36-hours instead of one-year/24-hour)
- Flow rate, volume, and sediment transport
- Channel Protection
- Sheer Stress concept (a Fairfax County method)
- Site-specific design storm determination in Prince George County, MD, LID Hydrology Manual
- Need to define the top end (how much is enough)
- Criteria that is simple and understandable
- Identify incremental progress
- Identify basic fundamental standards, but provide local options of more complex methods
- Accountability

Mr. Crafton commented that Virginia is a very diverse state, particularly in terms of sophistication of both the designers and the plan reviewers from one locality to another. Part of the struggle with criteria and methodology is creating something that is as effective as we can make it but at the same time simple and understandable for people with less training and experience.

The workgroup discussed channel adequacy and the need for a review of the current criteria. Mr. Crafton suggested that perhaps a more efficient way to address this issue is to establish a small group within the larger work group and have them discuss, evaluate and present their conclusions to the full workgroup.

Mr. Crafton noted that DCR has asked the Center for Watershed Protection to develop several rainfall analyses to determine if there is any significant difference in the rainfall patterns and distribution in various regions of Virginia.

Mr. Hirschman suggested and the workgroup agreed that at the next meeting it might be useful to have a presentation on the water quantity aspects of the work that has been done for the Northern Virginia Regional Commission's draft LID Supplement. Fernando Pasquel, of Baker Engineering – the consultant that assisted the NVRC in developing the LID Supplement – agreed to provide a presentation, depending on the date of the next meeting. Darryl Cook also suggested that DCR invite Dr. Greg Hancock, of the College of William and Mary, to make a presentation on the detention BMP study his group has been conducting in James City County.

Mr. Crafton stated that the regular TAC meetings would not start until mid-June. The work group will need to meet several times prior to that and be prepared to make specific recommendations to the regulatory TAC at their June or July meeting at the latest.

Work group members asked that DCR develop a draft work plan prior to the next meeting, so participants have a clearer idea of the specific aims and confidence that we are making appropriate progress. Mr. Lee Hill, DCR's SWM Program Manager, reminded the group that DCR is not developing the recommendations. DCR can coordinate the meeting and we can provide targets, but the work group should recommend to DCR what needs to be done.

Mr. Crafton indicated he is not sure we have yet captured all the issues members are concerned about or have heard them in a form that can be related back to a larger group. He requested that the members email him their concerns and suggestions. Mr. Crafton stated with that information received, he can develop a work plan and provide it to the members prior to the next meeting.

Mr. Crafton said that DCR will send out an e-mail to the workgroup members regarding potential dates for the next meetings. He thanked the members for their willingness to help with this important matter. The meeting adjourned at approximately 4:00 pm.

Respectfully Submitted,

Scott Crafton

ATTACHMENT 1

DCR Stormwater Management Regulation Revision Process
Water Quantity Control Criteria Work Group Meeting
April 22, 2008 (Earth Day)
Patrick Henry Building, State Capitol Complex
Richmond, Virginia

<u>Agenda</u>

1. Introductions/Logistical items *(Scott Crafton, DCR)*

2. Discussion of current water quantity criteria, context of regulation revision process, and work group goals *(Scott Crafton, DCR)*

3. Comments of proposed DCR approach to overall compliance and technical issues/recommendations regarding the water quantity element *(David Hirschman, Center for Watershed Protection)*

4. General work group discussion (concerns, suggestions, questions, etc.) *(Scott Crafton, DCR)*

5. Set next meeting date *(Scott Crafton, DCR)*

6. Adjourn

ATTACHMENT 2

DCR SWM/E&S "QUANTITY CONTROL" CRITERIA DISCUSSION

1. Runoff Volume Reduction and/or Recharge Requirements: NONE currently. Typically, this type of requirement targets the rainfall events that create little or no stormwater runoff, but that produce much of the annual groundwater recharge that occurs at the development site.

Members of DCR's Technical Advisory Committee (TAC) for the Stormwater Management Regulation revision have recommended adding (unspecified) requirements pertaining to groundwater recharge and/or runoff reduction. However, ***it is unclear (1) whether there is a clear enough option available that is also politically acceptable to the range of stakeholders involved with the state's Stormwater Management Program, or (2) whether a separate requirement will be necessary, given the runoff reduction methodology DCR is proposing.***

The intent of the recharge and/or volume reduction criterion is to maintain groundwater recharge rates at development sites to preserve existing water table elevations and support natural flows in streams and wetlands. Under natural conditions, the amount of recharge that occurs at a site is a function of slope, soil type, vegetative cover, precipitation and evapotranspiration. Sites with natural ground cover, such as forest and meadow, typically exhibit higher recharge rates, lower runoff volumes and greater transpiration losses than sites dominated by impervious cover. Since development increases impervious cover, a net decrease in recharge rates is inevitable.

As noted above, the water quality protection criteria proposed to DCR by the CWP rests on a foundation of runoff volume reduction. However, this is an integrated methodology based on the science of stormwater management, rather than on a specific requirement set forth in the regulations. Therefore, ***DCR expects the regulations to result in substantial runoff reduction, including groundwater recharge, even if there is no stated requirement in the regulations.***

2. Water Quality Requirements (Treatment Volume): Currently aimed at capturing of the *first flush* of runoff; therefore, most treatment BMPs are sized based on capturing the first ½-inch to 1-inch of runoff from impervious surfaces. Typically the treatment volume targets the rainfall events that transport the majority of stormwater pollutants off of the development site.

Several years ago, as part of legislation introduced by Fairfax County addressing stream restoration projects, a definition of *"Water Quality Volume"* was added to the Stormwater Management Act. However, this definition was included to clarify issues pertinent to that specific legislation rather than water quality treatment of runoff in general. Stormwater management experts across the nation are moving away from focusing on the first flush and BMP pollutant removal efficiencies as the keys to managing water quality. The newer thinking is that we need to focus on runoff volume reduction as the principle method of reducing the mass load of pollution from runoff. Practices that are more purely treatment practices, such as filters, ponds and constructed wetlands, should be back-up solutions.

Chapter 2 of the current *Virginia Stormwater Management Handbook (1999)* also discusses the method recommended by the Center for Watershed Protection (CWP) that focuses on treating runoff from the 1-inch rainfall event (the 90^{th} percentile rainfall event in the Chesapeake Bay region). This approach is actually the foundation for what DCR is proposing for BMP treatment volumes, as discussed below.

Proposed: The Center for Watershed Protection (CWP) has proposed to DCR that the treatment volume (Tv) for Level 1 treatment practices generally be treatment of the runoff from a 1-inch rainfall. Level 1 treatment practices are aimed at achieving the median removal rate for the target pollutant (in this case, phosphorus) reflected in the research projects included in the National Pollutant Removal Performance Database (NPRPD). The CWP has proposed that the Tv for Level 2 treatment practices vary, specific to each practice, as a multiple of the Level 1 version of that practice (multiples are 1.1, 1.25 or 1.5, depending on the practice). Therefore, the Tv is specific to each practice and each level of the practice. These recommendations have been developed based on an extensive review of the NPRPD, ferreting out the critical design features that appear to have resulted in improved BMP performance.

3. Channel Protection Requirements: Targets the storm events that generate bankfull and sub-bankfull flows in downstream channels and cause downstream channel erosion. Currently, the SWM regulations require compliance with Minimum Standard 19 of the Virginia Erosion and Sediment Control Regulations (4 VAC 50-30-40.19). This standard requires that *properties downstream from development sites be protected from sediment deposition, erosion, and damage due to increases in volume, velocity, and peak flow rate of stormwater runoff.* The specific design criteria specify that downstream *natural channels* be analyzed for adequacy to assure they can convey the post-development 2-year/24 hour peak discharge within the channel banks and at a non-erosive velocity. In addition, *man-made channels* must be analyzed for adequacy to assure they can convey the 10-year/24-hour peak discharge within the channel banks and the 2-year/24-hour discharge at a non-erosive velocity. This requirement typically results in employment of practices that capture the post-development runoff volume, with the release approximating the pre-development storm flow.

Proposed: DCR does not yet have a specific proposal for an updated channel protection requirement. That is one of the purposes of this Stormwater Quantity Control Work Group. However, the CWP has proposed that DCR consider moving to a different design storm for this purpose. Other jurisdictions in the Bay region have moved to requiring detention of runoff from the *post-development* one-year/24-hour storm, with a release period of 24 hours. However, some stormwater management experts believe even this storm may result sizing BMPs to be larger than necessary to adequately protect stream channels. ***This is one of the most important issues the Work Group needs to discuss.***

4. Overbank Flood Protection Requirements: Currently, DCR requires control of the post-development 10-year/24-hour storm back to the pre-development release rate. This targets the large and relatively infrequent storm events that cause streams to leave their banks and spill over into the floodplain, causing damage to infrastructure and streamside property. ***DCR does not expect to change this criterion, since it is widely accepted and used for this purpose.***

5. Extreme Flood Protection Requirements: This targets the largest, most infrequent storm events that cause catastrophic flooding and threaten floodplain structures and public safety (e.g., 100-year flood). DCR does not require that BMPs be sized to hold back the 100-year storm, but practices must be designed by bypass flows larger than the 10-year storm. For example, emergency spillways of ponds must be able to safely bypass the 100-year/24-hour storm in order to protect the structural integrity of the dams and risers. ***DCR does not expect to change this criterion, since it is widely accepted and used for this purpose.*** The Federal Emergency Management Agency (FEMA) maps the 100-year flood plain, based on the expected flood elevation of the 100-year frequency design storm. The mapped 100-year floodplain is important because it is used to designate and implement the National Flood Insurance Program. Most localities in Virginia have a Floodplain Management Ordinance that controls development within the 100-year floodplain.

The relationship between the five stormwater sizing criteria is best understood visually as a layer cake, with recharge volume being the thinnest layer at the top and extreme storm control comprising the thickest layer at the bottom. **Figure 1** illustrates the relationship between the five stormwater sizing criteria.

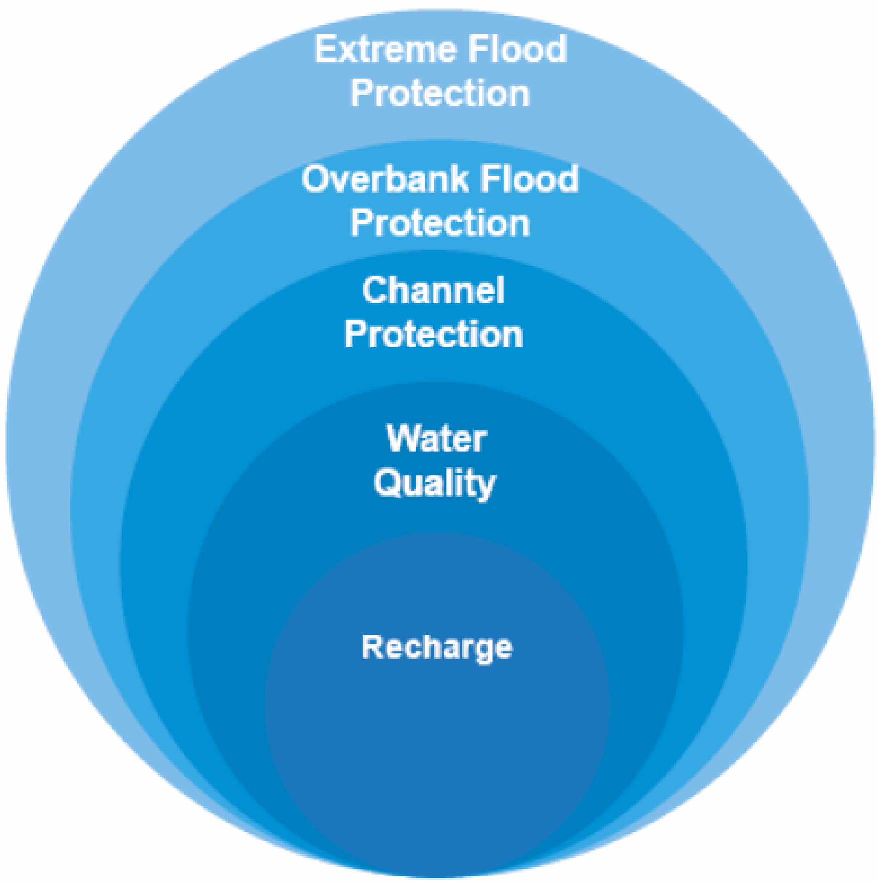

Figure 1: Graphic Representation of the Unified Stormwater Sizing Criteria

RECHARGE AND VOLUME REDUCTION CRITERIA (RR_v)

A number of states have recently developed design criteria to promote recharge and/or runoff volume reduction at development sites **(Table 1)**. Each of the states use a slightly different approach; the pros and cons of each design approach can be found in the issue papers developed for the recently published *Minnesota Stormwater Manual (2006)*

The most widely applied recharge and/or volume reduction sizing criterion is the recharge volume approach. The objective of the criterion is to mimic the average annual recharge rate for the prevailing hydrologic soil group(s) present at a development site. Therefore, the recharge volume is calculated as a function of annual pre-development recharge for a given soil group, average annual rainfall volume, and the amount of impervious cover at a site. The recharge volume is considered to be part of the total water quality volume provided at a development site and, therefore, does not require additional structural BMPs when water quality treatment is also required (see below). Additionally, recharge can be achieved either by structural BMPs (e.g., infiltration, bioretention, and filtration), non-structural BMPs (e.g., impervious disconnection, open space preservation), or a combination of both.

Table 1: Example Recharge and Volume Reduction Criteria

MD/MA	Recharge volume based on regional annual recharge rates for hydrologic soil groups present at the site
NJ	Use of specialized recharge model to determine location and volume of recharge needed at the site
WI/PA	Infiltrate the increase in runoff volume from pre- to post development for the two year-24 hour design storm event
MN	Allow for stormwater credits that provide recharge
Various	Infiltrate the first half inch of runoff

Recharge and/or volume reduction stormwater criteria offer additional stormwater management benefits, since they promote more on-site infiltration of stormwater runoff. This enables communities to offer stormwater credits that reduce the water quality storage volume. Recharge credits provide real incentives to apply low-impact development techniques at development sites that can reduce the number, size and cost of structural stormwater BMPs. ***To maximize recharge and volume reduction, designers must explore how to use pervious areas for infiltration early in the site layout process.***

Note, however, that the infiltration of polluted stormwater runoff is not always desirable or even possible at some development sites. Therefore, most recharge and/or infiltration requirements include criteria to reflect special site conditions, protect groundwater quality, and avoid common nuisance issues. For example, they may require:

- The pretreatment of stormwater runoff prior to infiltration in some land use categories or pollution source areas (e.g. parking lots, roadways).
- That recharge be restricted or prohibited at specific industrial, commercial and transport-related operations designated as potential stormwater hotspots.

- That recharge be prohibited or otherwise restricted within the vicinity of wellhead protection areas, individual wells, structures, basins.
- That recharge be restricted or prohibited within certain geological zones, such as active karst, and in areas adjacent to unstable or fill slopes.
- That recharge requirements be reduced or waived for minor redevelopment projects.

DCR expects to include such specific criteria in the design standards and specifications for the various treatment practices that accomplish recharge and runoff reduction.

CHANNEL PROTECTION CRITERIA (Cp_v)

Historically, two-year peak discharge control has been the most widely applied local criteria to control channel erosion in most states, and many communities continue to use it today. Two-year peak control seeks to keep the post-development peak discharge rate for the 2-year/24-hour design storm at pre-development rates. The reasoning behind this criterion is that the bankfull discharge for most streams has a recurrence interval of between 1 and 2 years, with approximately 1.5 years as the most prevalent **(Leopold, 1964 and 1994)**, and maintaining this discharge rate should act to prevent downstream erosion.

Recent research, however, indicates that two-year peak discharge control does not protect channels from downstream erosion and may actually contribute to erosion since banks are exposed to a longer duration of erosive bankfull and sub-bankfull events **(MacRae, 1993, MacRae, 1996, McCuen and Moglen, 1988)**. Thus, while two-year peak discharge control may have some value for overbank flood control, it is not effective as a channel protection criterion, since it may actually extend the duration of erosive velocities in the stream and increase downstream channel erosion.

Regulators are being encouraged to adopt new channel protection criteria (and eliminate two-year peak discharge control requirements) when they revise or adopt local stormwater ordinances. Some examples of the channel protection criteria that are in use today are shown in **Table 2**.

Table 2: Example Channel Protection Criteria

MD,VT,GA,NY	24 hour detention of the one-year 24 hour storm
WA	Match predevelopment peaks for duration of storms from 0.5 to 50 years using simulation models
ONT	Distributed Runoff Control
WI/MN	Infiltrate excess runoff volume from 2 year storm
Various	Control two year storm to one year levels
Various	Performance criteria, such as outlet energy controls, level spreaders, maintenance of stream buffers

The most widely recommended channel protection criterion in the last few years is to provide 24 hours of extended detention for the runoff generated from the 1-year/24-hour design storm. This runoff volume is stored and gradually released over a 24-hour period so that critical erosive velocities in downstream channels are not exceeded over the entire storm hydrograph. As a very rough rule of thumb, the storage capacity needed to provide channel protection is about 60% of the one-year storm runoff volume. This channel protection criterion has recently been adopted by the States of Maryland, New York, Vermont, and Georgia, and is relatively easy to compute at most development sites using hydrologic models. However, as noted above, ***some stormwater experts are beginning to question whether even this design criterion will result in BMPs that are larger and more costly than needed to actually protect receiving channels.***

INTEGRATING MS-19 WITH CHANNEL RESULTING PROTECTION CRITERIA

One aim pertaining to the water quantity control criteria in the Stormwater Management (SWM) Regulations is to integrate the channel protection criteria currently set forth in the Erosion and Sediment (E&S) Control Regulations into the SWM Regulations, and having the E&S Control then refer to the SWM regulations.

As currently constructed, MS-19 has nearly two pages of specific criteria related to stream channel protection. However, the over-riding requirements are stated as performance criteria aiming to assure that runoff discharges into and *adequate* *channel* (NOT outfall), and that receiving channels/streams are protected from sediment deposition, erosion, and damage due to increases in volume, velocity and peak flow of stormwater runoff for the stated design storm (4 VAC 50-30-40.19). Furthermore, all protective measures are to be employed in a manner which minimizes impacts on the physical, chemical and biological integrity of the receiving waters (4 VAC 50-30-40.19.k).

There appears to be broad agreement that the channel protection criteria that Virginia has been requiring for many years *is not working effectively*. This is evidenced by the significant amount of stream channel degradation that has taken place, even with the current requirements in place. There also appears to be broad agreement among local and state government officials and consulting engineers and site designers that the criteria need to be improved to provide better protection and better accountability. The existing performance criteria appear to be reasonable for achieving the goal of effective channel protection. ***The challenge for the Work Group will be to improve the more specific criteria in a manner that comports with the general performance criteria.***

ACCOUNTING FOR THE EFFECT OF RUNOFF REDUCTION ON RUNOFF HYDROGRAPHS

See separate handout.

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ATTACHMENT 3

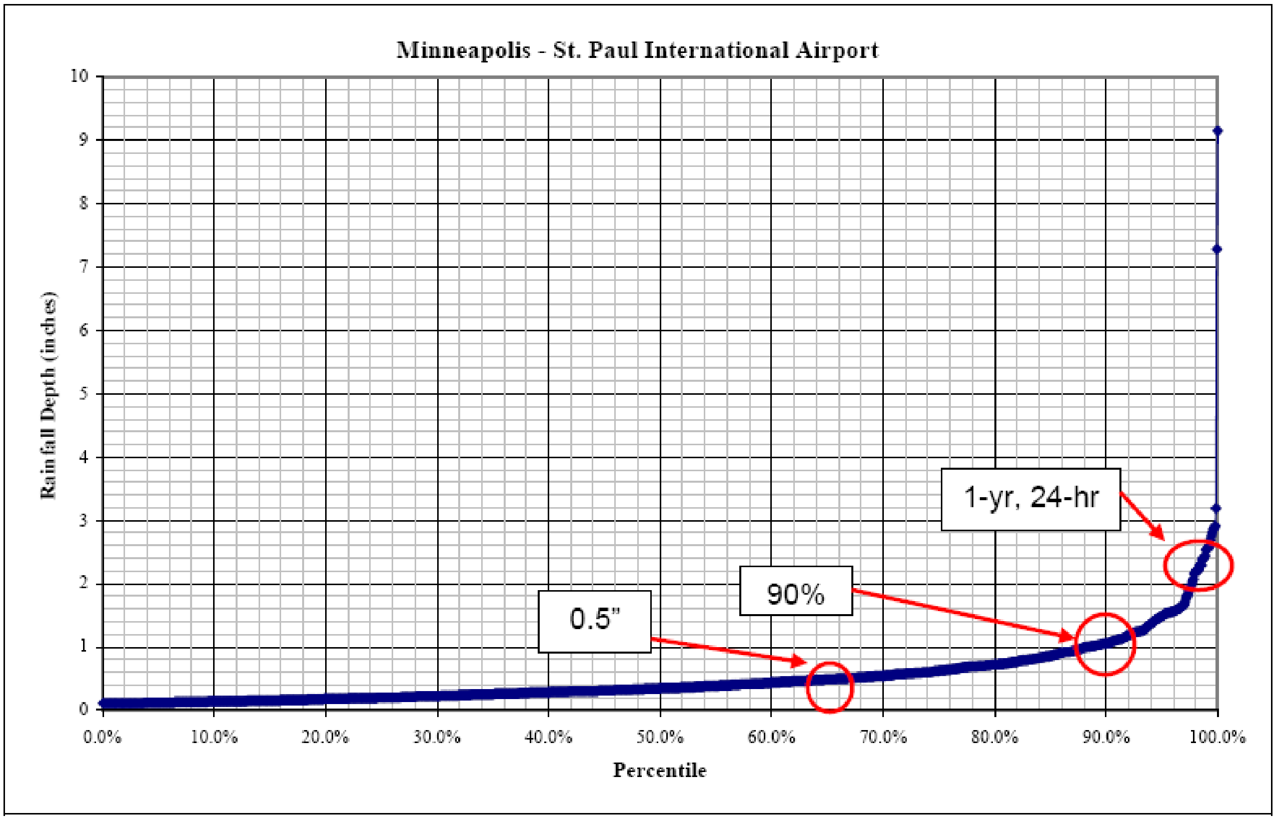


Figure 4.3: Rainfall Frequency Spectrum for Minneapolis-St. Paul, MN (1971-2000) with Several Noteworthy Rainfall Events Identified

ATTACHMENT 4

Table 4.8. Recommended Stormwater Criteria for Design Manuals	
CRITERION #4: STABLE ENVIRONMENTAL CONVEYANCE (SEC) – Convey Stormwater to Protect Downstream Channels	
Explanation	The stormwater system should be designed so that increased post-development discharges that are NOT mitigated through application of Criteria #1 through #3 will not erode natural channels or steep slopes. This will protect in-stream habitats and reduce in-channel erosion. Conveyance systems can be designed to reduce stormwater volume, create non-erosive velocities, incorporate native vegetation, and, in some cases, restore existing channels that are degraded. This design process involves careful analysis of the downstream system – beginning with the site's position within a watershed or drainage area. First, compare the size of the on-site drainage area at each of the site's discharge points to the total drainage area of the receiving channel or waterway. Note that the point of analysis may not always be the property boundary of the site, but the point where the site's discharge joins a natural drainage swale, channel, stream, or waterbody. The recommended standard below presents a tiered system for SEC compliance based on the site/drainage area analysis discussed above.
Recommended Standards	At each discharge point from the site, if the on-site drainage area is LESS than 10% of the total contributing drainage area to the receiving channel or waterbody, then the following Tier 1 performance standards shall apply: Tier 1 Performance Standards ▪ Wherever practical, maintain sheetflow to riparian buffers or vegetated filter strips. Vegetation is buffers or filter strips shall be preserved or restored where existing conditions do not include dense vegetation (or adequately sized rock in arid climates). ▪ Energy dissipators and level spreaders shall be used to spread flow at outfalls ▪ On-site conveyances shall be designed to reduce velocity through a combination of sizing, vegetation, check dams, and filtering media (e.g., sand) in the channel bottom and sides ▪ If flows cannot be converted to sheetflow, they shall be discharged at an elevation that will not cause erosion or require discharge across any constructed slope or natural steep slopes. ▪ Outfall velocities shall be non-erosive from the point of discharge to the receiving channel or waterbody where the discharge point is calculated. At each discharge point from the site, if the on-site drainage area is GREATER than 10% of the total contributing drainage area to the receiving channel or waterbody, then the Tier 1 performance standards shall apply PLUS the following Tier 2 performance standards: Tier 2 Performance Standards ▪ Sites greater than 10 acres (or a site size deemed appropriate by the local program) shall perform a detailed downstream (hydrologic and hydraulic) analysis based on post-development discharges. The downstream analysis shall extend to the point where post-development

Table 4.8. Recommended Stormwater Criteria for Design Manuals	
CRITERION #4: STABLE ENVIRONMENTAL CONVEYANCE (SEC) – Convey Stormwater to Protect Downstream Channels	
	discharges have no significant impact (and do not create erosive conditions) on receiving channels, waterbodies, or storm sewer systems. ▪ If the downstream analysis confirms that post-development discharges will have an impact on receiving channels, waterbodies, or storm sewer systems, then the site shall incorporate some or all of the following to mitigate downstream impacts: (1) Site design techniques that decrease runoff volumes and peak flows. (2) Downstream stream restoration or channel stabilization techniques, as permitted through local, state, and federal agencies. (3) 24-hour detention of the volume from post-development 1-year, 24-hour storm (the volume is stored and gradually released over a 24-hour period). Runoff volumes controlled through the application of VC and WQv measures (Criteria #2 & 3, **Tables 4.6** and **4.7**) may be given credit towards meeting storage requirements. Discharges to cold-water fisheries should be limited to 12-hour detention. ▪ Sites less than 10 acres (or a site size deemed appropriate by the local program) shall use a combination of the mitigation techniques listed above and verify that stormwater measures provide 12 to 24 hour detention of the volume from post-development 1-year, 24-hour storm (again, allowing credits through the application of VC and WQV measures). A detailed downstream analysis is not required unless the local program identifies existing downstream conditions that warrant such an analysis.
Candidate BMPs to Meet Standards	▪ Water quality swales ▪ Grass swales ▪ Level spreaders & energy dissipators ▪ Riparian and flood plain restoration ▪ Bioretention with extra volume of soil media ▪ Pervious parking with underground storage ▪ Outfall designs that use natural channel and velocity reduction features ▪ Ponds and pond/wetland systems that provide peak flow control
Examples from Existing Programs – See Tool #5, Manual Builder, for more examples & links	Stormwater Management Manual for Western Washington – Volumes I & V http://www.ecy.wa.gov/programs/wq/stormwater/manual.html#How_to_Find_the_Stormwater_Manual_on_the North Carolina State University, Stormwater Engineering Group – Bioretention Design Spreadsheet http://www.bae.ncsu.edu/stormwater/downloads.htm (system to assign detention credit to bioretention) North Central Texas Council of Governments – Integrated Stormwater Management Design (iSWMD™ for Site Development – Ch. 1., Stormwater Management System Planning & Design http://iswm.nctcog.org/Documents/Site_Development_Manual.asp Henrico County, Virginia Environmental Program Manual -- Ch. 9, Minimum Design Standards, 9.01, Energy Dissipater http://www.co.henrico.va.us/works/eesd/

ATTACHMENT 5: LAWS AND REGULATIONS

EROSION AND SEDIMENT CONTROL LAW:

§ 10.1-561. State erosion and sediment control program.

A. The Board shall develop a program and promulgate regulations for the effective control of soil erosion, sediment deposition, and nonagricultural runoff that must be met in any control program to prevent the unreasonable degradation of properties, stream channels, waters and other natural resources in accordance with the Administrative Process Act (§ 2.2-4000 et seq.). Stream restoration and relocation projects that incorporate natural channel design concepts are not man-made channels and shall be exempt from any flow rate capacity and velocity requirements for natural or man-made channels as defined in any regulations promulgated pursuant to this section, § 10.1-562, or 10.1-570. Any land-disturbing activity that provides for stormwater management intended to address any flow rate capacity and velocity requirements for natural or man-made channels shall satisfy the flow rate capacity and velocity requirements for natural or man-made channels if the practices are designed to (i) detain the water quality volume and to release it over 48 hours; (ii) detain and release over a 24-hour period the expected rainfall resulting from the one year, 24-hour storm; and (iii) reduce the allowable peak flow rate resulting from the 1.5, 2, and 10-year, 24-hour storms to a level that is less than or equal to the peak flow rate from the site assuming it was in a good forested condition, achieved through multiplication of the forested peak flow rate by a reduction factor that is equal to the runoff volume from the site when it was in a good forested condition divided by the runoff volume from the site in its proposed condition, and shall be exempt from any flow rate capacity and velocity requirements for natural or man-made channels as defined in any regulations promulgated pursuant to § 10.1-562 or 10.1-570.

EROSION AND SEDIMENT CONTROL REGULATIONS:

4VAC50-30-40. ***Minimum standards***.

An erosion and sediment control program adopted by a district or locality must be consistent with the following criteria, techniques and methods: . . . .

19. Properties and waterways downstream from development sites shall be protected from sediment deposition, erosion and damage due to increases in volume, velocity and peak flow rate of stormwater runoff for the stated frequency storm of 24-hour duration in accordance with the following standards and criteria:

a. ***Concentrated stormwater runoff leaving a development site shall be discharged directly into an adequate natural or man-made receiving channel, pipe or storm sewer system. For those sites where runoff is discharged into a pipe or pipe system, downstream stability analyses at the outfall of the pipe or pipe system shall be performed.***

b. Adequacy of all channels and pipes shall be verified in the following manner:

(1) The applicant shall demonstrate that the total drainage area to the point of analysis within the channel is one hundred times greater than the contributing drainage area of the project in question *(NOTE: This is often referred to as the 1% Rule.)*; or

(2)(a) ***Natural channels shall be analyzed by the use of a two-year storm to verify that stormwater will not overtop channel banks nor cause erosion of channel bed or banks.***

(b) ***All previously constructed man-made channels shall be analyzed by the use of a ten-year storm to verify that stormwater will not overtop its banks and by the use of a two-year storm to demonstrate that stormwater will not cause erosion of channel bed or banks; and***

(c) ***Pipes and storm sewer systems shall be analyzed by the use of a ten-year storm to verify that stormwater will be contained within the pipe or system.***

c. If existing natural receiving channels or previously constructed man-made channels or pipes are not adequate, the applicant shall:

(1) Improve the channels to a condition where a ten-year storm will not overtop the banks and a two-year storm will not cause erosion to channel the bed or banks; or

(2) Improve the pipe or pipe system to a condition where the ten-year storm is contained within the appurtenances;

(3) Develop a site design that will not cause the pre-development peak runoff rate from a two-year storm to increase when runoff outfalls into a natural channel or will not cause the pre-development peak runoff rate from a ten-year storm to increase when runoff outfalls into a man-made channel; or

(4) Provide a combination of channel improvement, stormwater detention or other measures which is satisfactory to the plan approving authority to prevent downstream erosion.

d. The applicant shall provide evidence of permission to make the improvements.

e. All hydrologic analyses shall be based on the existing watershed characteristics and the ultimate development condition of the subject project.

f. If the applicant chooses an option that includes stormwater detention, he shall obtain approval from the locality of a plan for maintenance of the detention facilities. The plan shall set forth the maintenance requirements of the facility and the person responsible for performing the maintenance.

g. Outfall from a detention facility shall be discharged to a receiving channel, and energy dissipators shall be placed at the outfall of all detention facilities as necessary to provide a stabilized transistion from the facility to the receiving channel.

h. All on-site channels must be verified to be adequate.

i. Increased volumes of sheet flows that may cause erosion or sedimentation on adjacent property shall be diverted to a stable outlet, adequate channel, pipe or pipe system, or to a detention facility.

j. In applying these stormwater management criteria, individual lots or parcels in a residential, commercial or industrial development shall not be considered to be separate development projects. Instead, the development, as a whole, shall be considered to be a single development project. Hydrologic parameters that reflect the ultimate development condition shall be used in all engineering calculations.

k. ***All measures used to protect properties and waterways shall be employed in a manner which minimizes impacts on the physical, chemical and biological integrity of rivers, streams and other waters of the state.***

Statutory Authority

§§10.1-502 and 10.1-561 of the Code of Virginia.

Historical Notes

Derived from VR625-02-00 §4; eff September 13, 1990; amended, Virginia Register Volume 11, Issue 11, eff. March 22, 1995.

STORMWATER MANAGEMENT LAW:

§ 10.1-603.4. Development of regulations.

The Board is authorized to adopt regulations that specify minimum technical criteria and administrative procedures for stormwater management programs in Virginia. The regulations shall: . . .

7. Require that stormwater management programs maintain after-development runoff rate of flow and characteristics that replicate, as nearly as practicable, the existing predevelopment runoff characteristics and site hydrology, or 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. Any land-disturbing activity that provides for stormwater management shall satisfy the conditions of this subsection if the practices are designed to (i) detain the water quality volume and to release it over 48 hours; (ii) detain and release over a 24-hour period the expected rainfall resulting from the one year, 24-hour storm; and (iii) reduce the allowable peak flow rate resulting from the 1.5, 2, and 10-year, 24-hour storms to a level that is less than or equal to the peak flow rate from the site assuming it was in a good forested condition, achieved through multiplication of the forested peak flow rate by a reduction factor that is equal to the runoff volume from the site when it was in a good forested condition divided by the runoff volume from the site in its proposed condition, and shall be exempt from any flow rate capacity and velocity requirements for natural or man-made channels as defined in any regulations promulgated pursuant to this section, or any ordinances adopted pursuant to § 10.1-603.3 or 10.1-603.7;

PROPOSED STORMWATER MANAGEMENT REGULATIONS (To date):

4VAC 50-60-66 Water Quantity

In order to protect state waters from the potential harms of unmanaged quantities of stormwater runoff, the following technical criteria and statewide standards for stormwater management shall apply to land disturbing activities:

A. Properties and state waters receiving stormwater runoff from any land-disturbing activity shall be protected from sediment deposition, erosion and damage due to changes in runoff rate of flow and hydrologic characteristics, including but not limited to, changes in volume, velocity, frequency, duration, and peak flow rate of stormwater runoff in accordance with the minimum water quantity standards set out in this section.

B. Pursuant to §10.1-603.4 subsection 7, a local program shall require that land disturbing activities:

1. Maintain post-development runoff rate of flow and runoff characteristics that replicate, as nearly as practicable, the existing predevelopment runoff characteristics and site hydrology.

2. If stream channel erosion or localized flooding exists at the site prior to the proposed land disturbing activity, the project shall improve to the extent practicable upon the contributing share of the existing predevelopment runoff characteristics and site hydrology.

C. For the purposes of determining compliance with subsection B, a local program shall require the following:

1. Pre-development runoff characteristics and site hydrology shall be verified by physical surveys, geotechnical investigations, and calculations that are consistent with good engineering practices that are acceptable to the local program authority.

2. Flooding and channel erosion impacts to receiving streams due to land-disturbing activities shall be calculated for each point of discharge from the land disturbance and such calculations shall include any runoff from the balance of the watershed which also contributes to that point of discharge. Flooding and channel erosion impacts shall be evaluated taking the entire upstream watershed into account, including the modifications from the planned land disturbance. Good engineering practices and calculations shall be used to demonstrate post development runoff characteristics and site hydrology, and flooding and channel erosion impacts.

3. For purposes of computing predevelopment runoff, all pervious lands in the site shall be assumed prior to development to be in good condition (if the lands are pastures, lawns, or parks), with good cover (if the lands are woods), or with conservation treatment (if the lands are cultivated); regardless of conditions existing at the time of computation. Predevelopment runoff calculations utilizing other land cover values may be utilized where stream channel erosion or localized flooding at the site does not exist provided that it is demonstrated to and approved by the local program authority that actual site conditions warrant such considerations.

D. Notwithstanding the requirements of subsection C, any land disturbing activity shall be deemed to have satisfied the requirements of subsection B if the practices implemented on the site are designed to:

1. Detain the water quality volume and to release it over 48 hours;

2. Detain and release over a 24-hour period the expected rainfall resulting from the one year, 24 hour storm; and

3. Reduce the allowable peak flow rate resulting from the 1.5, 2, and 10-year, 24-hour storms to a level that is less than or equal to the peak flow rate from the site assuming that it was in good forested condition, achieved through multiplication of the forested peak flow rate by a reduction factor that is equal to the runoff volume from the site when it was in a good forested condition divided by the runoff volume from the site in its proposed condition.

Such land disturbing activity shall further be exempt from any flow rate capacity and velocity requirements for natural or manmade channels as defined in any other section of this regulation.

ATTACHMENT 6

Accounting for the Effect of Runoff Reduction on Runoff Hydrographs
PRELIMINARY DRAFT – NOT A FINAL PRODUCT – WORK IN PROGRESS!!!
Center for Watershed Protection, 04/21/08

1. Background and Introduction

Historically, stormwater management has focused on peak runoff rate control, which requires a site designer to generate a post-development runoff hydrograph and a pre-development runoff hydrograph and manage the difference between the two.

More recently, site designers have been introduced to water quality control criteria that are intended to manage the "capture and treat" (e.g. water quality) volume,

Most recently, communities have developed stormwater runoff reduction criteria that specify a runoff volume that must be "captured and reduced" (reused, evaporated, infiltrated or otherwise retained on site). A particular challenge is providing credit for these runoff reduction volumes within rainfall/runoff models.
In principle, when runoff reduction practices are used to capture and retain or infiltrate runoff, downstream stormwater management practices shouldn't have to detain, retain or otherwise treat the volume that is removed. In other words, runoff reduction should be accounted for in stormwater runoff computations

While it is not easy to predict the absolute hydrograph modification provided by reducing stormwater runoff volumes, it is clear that reducing runoff volumes will have an impact on the runoff hydrograph of a development site. The challenge facing stormwater managers and site designers is developing a hydrograph generating technique that provides adequate credit for stormwater runoff volumes that are reduced on site.

2. Objectives for Integration

In order to be useful to stormwater managers and site designers, the method developed and used must meet a number of objectives:

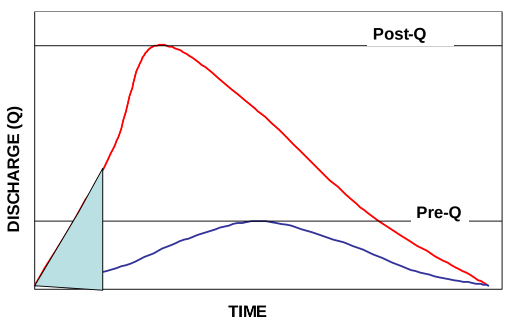
1. Field performance – solves real problems (water quality, channels, long term maintenance/performance)
2. More efficiency – doesn't lead to the overbuilding of BMPs (size, #)
3. Incentivizes RR/BSD – leads to meaningful results if the designer applies ample effort to use RR practices
4. Simple – easy to understand & use, fits into spreadsheets + TR55, other common models
5. Allows range of practices – broadens the suite of BMPs to use at a site – basins are not "automatic."

6. Accountability for the local PW guys – today's plan approvals do not equal tomorrow's drainage complaints
7. Defensible – makes sense with the site hydrology; engineers believe it is realistic and plausible
8. Accurate – reflects actual site hydrology
9. Adaptable to Different Pollutants -- Addresses pollutants of concern for different applications
10. Relevant at Subwatershed – Can be tied to stormwater benchmarks for subwatershed, such as flow, volume, load reduction

3. Different Approaches and Methods

There are a variety of approaches that can be used to adjust the runoff hydrograph to account for the effect of runoff reduction practices in a site drainage area. This section describes five approaches, all of which use the NRCS unit hydrograph method as a baseline. For some methods, a hydrograph for the site without runoff reduction practices is generated, which is then adjusted. Other methods initially adjust the runoff depth that results from a site with runoff reduction practices, and then generates a hydrograph. Different approaches are discussed below.

Truncated Hydrograph (Volume Diversion)
The truncated hydrograph approach applies runoff reduction in-line at the outlet of a drainage area. For this particular option, a runoff hydrograph for the original site prior to implementing runoff reduction practices is generated. The volume of runoff reduced by runoff reduction practices is then subtracted from the front portion of the hydrograph. If the amount of runoff reduced is less than the volume up to the hydrograph peak, then no reduction in the peak flow or time to peak is reflected. As a result, this approach often results in conservative design estimates of the resulting peak flow.



Hydrograph Scalar Multiplication
Similar to the previous approach, the hydrograph scalar approach begins by generating a hydrograph for the original site prior to implementing runoff reduction practices. In this particular approach, the hydrograph is then multiplied by a scalar, which adjusts the magnitude of the original site hydrograph. The scalar is simply the ratio of runoff generated

from the site with runoff reduction practices to the runoff generated from the original site (with no runoff reduction practices). The effect of runoff reduction practices is applied over the entire hydrograph rather than at the beginning. As a result, the degree to which the peak flow rate would be reduced is decreased, resulting in a conservative peak flow rate estimate.

Precipitation adjustment- Subtract retention from rainfall

This approach adjusts the NRCS runoff depth formula prior to generating a hydrograph, eliminating the need to develop an original site hydrograph. For this approach, the amount of runoff reduced is subtracted from the rainfall depth (Eqn. 1), and hydrograph calculations are subsequently performed.

$$Q = \frac{\left((P-R)-I_a\right)^2}{\left((P-R)-I_a\right)+S} \qquad (1)$$

where P=rainfall depth (in), R = Reduced Runoff (in), Q= Runoff (in), I_a *= initial abstraction, S = potential maximum retention after runoff begins*

The problem with this approach is that the volume of runoff reduced is never fully accounted for, as the change in runoff volume generated will always be less than the amount of runoff reduced. Further, adjusting the rainfall is not truly representative of what actually occurs over the site.

Adjusted CN

The Adjusted CN approach adjusts the NRCS runoff depth formula by changing the curve number (CN) for the portion of the site draining to runoff reduction practices. Site runoff is calculated using Equations 2-4. The CN can be adjusted to an improved site condition; for example, to a meadow in good condition.

$$S = \frac{1000}{CN} - 10 \qquad (2)$$

$$I_a = 0.2S \qquad (3)$$

$$Q = \frac{\left((P-I_a\right)^2}{\left((P-I_a\right)+S} \qquad (4)$$

This approach reduces the runoff generated from the site and the runoff peak flow rate; however, no delay in the time to peak is reflected. Further, the effect of runoff reduction is distributed over the entire course of the storm, as opposed to occurring at the beginning. As a result, the degree to which the peak flow rate would be reduced is decreased, resulting in a conservative peak flow rate estimate.

Runoff adjustment - Subtract retention from runoff
The runoff adjustment approach also adjusts the NRCS runoff depth formula prior to generating a hydrograph. The amount of runoff reduced is subtracted from the calculated site runoff (Eqn. 5). A hydrograph is then generated incrementally through the unit-hydrograph method that reflects the initial reduction of runoff volume and the subsequent time to peak delay and peak flow reduction.

$$Q = \frac{((P - I_a))^2}{((P - I_a)) + S} - R \qquad (5)$$

This approach seems to accurately describe what may occur over a site drainage area, but it is problematic in that TR-55 and TR-20 cannot be used to generate the resulting hydrograph. While the methodology is straightforward, the hydrograph convolutions are time-consuming and involved.

4. Preferred Method(s)

(A) Best Long-Term: Runoff adjustment - Subtract retention from runoff

Of the methods listed above, *Runoff adjustment – Subtract retention from runoff,* is the preferred method. The philosophy behind this method is the similar to the philosophy behind the *Truncated Hydrograph* method – site runoff reduction practices, will accept and retain a portion of the initial runoff during a given rain event, which will modify the ultimate volume of runoff from the site, as well as the shape of the ultimate runoff hydrograph.

The key difference between the two methods is how the initial runoff is "subtracted." As discussed above, for the *Truncated Hydrograph* method, a total site runoff hydrograph is created, and then the volume provided by the runoff reduction practices is subtracted from the hydrograph's rising limb. For the *Runoff adjustment – Subtract retention from runoff* method, the subtraction is performed at an earlier stage, before the site hydrograph is generated. In order to generate a site hydrograph for an entire storm event, the storm is divided into discreet time periods. For each time period, an excess runoff rate is determined based upon watershed characteristics and the amount of rainfall during that time period. This excess runoff rate is then translated into a hydrograph. The site hydrograph for the entire storm event is created by summing each of these hydrographs over the duration of the storm. Instead of making a subtraction from the site hydrograph, the *Runoff adjustment – Subtract retention from runoff* method subtracts each individual time period hydrograph, until the volume of runoff reduction has been reached.

This is the preferred method, because it not only subtracts the runoff reduction volume at the beginning of the hydrograph, but also tends to reduce the peak flow and extend the time to peak of the site hydrograph, all of which are expected effects of utilizing runoff reduction practices. The effects on peak flow and time to peak are due to the fact that a time period hydrograph extends longer than the period of rainfall it corresponds to. Therefore, subtraction of an initial number of time period hydrographs has a significant effect on the rising limb of the site hydrograph, but the effect is also extended through the peak, changing both the peak, and the time to peak.

While this preferred method appears to model the actual hydrology of runoff reduction practices most closely, it is a difficult and time-consuming method. Subtraction of time period hydrographs requires that the time period hydrographs be individually calculated throughout a storm event. This time-consuming activity is rarely performed, as there are many hydrology computer programs that have been designed to do this and calculate a total site hydrograph. However, existing hydrology programs do not have the capability to subtract individual hydrographs from the site hydrograph and account for runoff reduction practices in this manner.

(B) Good Choice for Short-Term: Adjusted CN

Given the software and assimilation challenges of the *Runoff adjustment* method, the second best option is *Adjusted CN.* This method is a plausible way to reduce volumes and peak rates, and fits into the models that are understood by design consultants and plan reviewers.

5. Next Steps

- Vet the various methods with DCR’s workgroup.
- Continue to flesh out the preferred methods, using examples and sample hydrographs to see the effect, and the actual benefit of applying RR practices.
- Perhaps work to develop some software applications (would require funding)
- Fold a preferred method into the Runoff Reduction compliance spreadsheet
- Use the integrated approach at future charettes

▪

ATTACHMENT 8

DRAFT Virginia Runoff Reduction Method, 04/1/08
Description of Overall Process

NOTES ON THE METHOD

- **Total Phosphorus (TP)** used as keystone pollutant. Total Nitrogen (TN) can also be calculated and BMP designs can address TN removal, but water quality compliance is based on TP.
- Each site also has a **Treatment Volume (Tv)** that is based on post-development land covers. The method uses more than just impervious cover to compute the Tv.
- BMPs are assigned **Runoff Reduction (RR)** and **Pollutant Removal (PR)** rates. Rates vary for Level 1 and Level 2 designs, based on ongoing research (these rates are provisional). Level 2 BMPs have design enhancements to boost performance (see Table 1).
- BMPs are sized and designed based on Level 1 and Level 2 design guidelines (see Tables 2 through 16). The applicable RR and PR rates are based on these sizing and design rules.

OVERVIEW OF METHOD

1. Utilize environmental site design (ESD) techniques to reduce impervious cover and maximize forest and open space cover. This will affect the post-development treatment volume and pollutant load.
2. For the site, measure post-development impervious, managed turf, and forest/open space land cover. If there is more than one Hydrologic Unit for the site, the land cover analysis should be done for each HU. The approval authority may define a planning area for the site where the land cover analysis should be done (e.g., a concentrated area of development within a larger parcel), although this should be based on equitable criteria. Guidance for various land covers is as follows:
    a. Impervious = roads, driveways, rooftops, parking lots, sidewalks, and other areas of impervious cover
    b. Managed Turf = land disturbed and/or graded for turf, including yards, rights-of-way, and turf intended to be maintained and mowed within commercial and institutional settings
    c. Forest/Open Space = pre-existing forest and open land, plus land to be reforested (according to standards), that will remain undisturbed and protected in an easement, deed restriction, protective covenant, etc. If land will be disturbed during construction, but treated with soil amendments, reforested according to the standards, and protected as noted above, then it may also qualify for forest cover.

3. Calculate weighted turf and weighted forest runoff coefficients based on hydrologic soil groups. Combined with impervious cover, the result will be a weighted site runoff coefficient. ***STEP 1 IN THE SPREADSHEET***.

Rv Coefficients				
	A soils	B Soils	C Soils	D Soils
Forest/Reforested	0.02	0.03	0.04	0.05
Managed Turf	0.15	0.20	0.22	0.25
Impervious Cover	0.95			

4. Calculate post-development TP loading & Treatment Volume for the site or each HU on the site. ***STEP 1 IN THE SPREADSHEET***.
5. Apply **Runoff Reduction (RR)** Practices on the site to reduce post-development treatment volume and load. The site designer should select the most strategic locations on the site to place RR practices (e.g., drainage areas with the most developed land). This will likely be an iterative process. Runoff reduction "volume credits" are based on the contributing drainage area (CDA) to each selected BMP. ***STEP 2 IN THE SPREADSHEET***.
6. Based on the RR practices selected, **Pollutant Removal (PR)** rates will be applied to BMPs that achieve both runoff reduction and pollutant removal functions. ***STEP 3 IN THE SPREADSHEET***.
7. If there is still a TP load to remove after applying RR and PR credits to the selected BMPs, the designer can:
    a. Select additional **RR** BMPs in ***STEP 2 OF THE SPREADSHEET***,
    b. Select additional **PR** BMPs in ***STEP 3 OF THE SPREADSHEET***.

RR and PR credits are applied to the BMP's CDA.
The ultimate goal is to reduce the load to "0."

The Cheat Sheet for the Design Exercises
Values are Provisional

Practice	RR (%)	PR- TP (%)	Space (% of CDA)
Bioretention	*40 to 80*	*25 to 50*	*5 to 10*
Infiltration	*50 to 90*	*25*	*3 to 5*
Filtering Practice	*0*	*60 to 65*	*3 to 5*
Dry Swale	*40 to 60*	*20 to 40*	*5 to 7*
Wet Swale	*0*	*20 to 40*	*5 to 7*
Grass Channel	*10 to 20*	*15*	*5 to 7*
ED Pond	*0 to 15*	*15*	*2 to 4*
Wet Pond	*0*	*50 to 75*	*3 to 5*
Constructed Wetland	*0*	*50 to 75*	*4 to 6*
Green Roof	*45 to 60*	*0*	*0*
Pervious Parking	*45 to 75*	*25*	*0*
Raintanks and Cisterns	*40*	*0*	*0*
Disconnection	*25 to 50*	*15*	*5 to 15*
Soil Amendments	*50 to 75*	*0*	*15 to 25*
Range of values is For Level 1 and 2 Designs, respectively			

Table 2 Bioretention Design Guidelines	
Level 1 Design (RR 40 TP: 25)	**Level 2 Design (RR: 80 TP: 50)**
TV= (Rv)(A)(1”)/12	TV= 1.25 (Rv)(A) (1”)/12
Filter media at least 24” deep	Filter media at least 36” deep
One form of accepted pretreatment	Two or more forms of accepted pretreatment
At least 75% plant cover	At least 90% plant cover, including trees.
One cell design	Two cell design
Underdrain	Infiltration design or underground stone sump
Both designs include media that is tested to have soil P index less than 10	
Sizing: Level 1: 5% of CDA **Level 2:** 10% of CDA.	

Table 3 Infiltration Design Guidelines	
Level 1 Design (RR: 50 TP: 25)	**Level 2 Design (RR: 90 TP: 25)**
TV= (Rv)(A) (1”)/12	TV= 1.1(Rv)(A) (1”)/12
CDA includes pervious area	CDA nearly 100% impervious
At least one form of pretreatment	At least two forms of pretreatment
Soil infiltration rate of 0.5 to 1.0 in/hr	Soil infiltration rates of 1.0 to 4.0 in/hr
Underdrain utilized	No underdrain needed
Sizing: Level 1: 3% of CDA **Level 2:** 5% of CDA.	

Table 4 Filtering BMP Design Guidance	
Level 1 Design (RR: 0 TP: 60)	**Level 2 Design (RR: 0 TP 65)**
TV= (Rv)(A) (1")/12	TV= 1.25 (Rv)(A) (1")/12
One cell design	Two cell design
Sand media	Sand media w/ organic layer
CDA includes pervious area	CDA nearly 100% impervious
Sizing: Level 1: 3% of CDA **Level 2:** 5% of CDA	

Table 5 Dry Swale Design Guidance	
Level 1 Design (RR: 40 TP: 20)	**Level 2 Design (RR: 60 TP: 40)**
TV= (Rv)(A) (1")/12	TV= 1.1 (Rv)(A) (1")/12
Swale slopes from <0.5% or >2.0%	Swale slopes from 0.5% to 2.0%
Soil infiltration rates less than 0.5 in	Soil infiltration rates exceed one inch
Swale served by underdrain	Lacks underdrain or uses underground stone sump
On-line design	Off-line or multiple treatment cells
Media depth less than 18 inches	Media depth more than 24 inches
Sizing: Level 1: 7% of CDA **Level 2:** 10% of CDA	

Table 6 Wet Swale Design Guidance	
Level 1 Design (RR: 10 TP: 20)	**Level 2 Design (RR: 20 TP: 40)**
TV= (Rv)(A) (1")/12	TV= 1.25 (Rv)(A) (1")/12
Swale slopes more than 1%	Swale slopes less than 1%
On-line design	Off-line swale cells
No planting	Wetland planting within swale cells
Note: Generally recommended only for flat coastal plain conditions with high water table. Linear wetland always preferred to wet swales	
Sizing: Level 1: 7% of CDA **Level 2:** 10% of CDA	

Table 7 Extended Detention (ED) Pond Guidance	
Level 1 Design (RR: 0 TP: 15)	**Level 2 Design (RR: 15 TP: 15)**
TV= (Rv)(A) (1")/12	TV = 1.25(Rv) (A) (1")/12
At least 15% of TV in permanent pool	More than 40% of TV in deep pool or wetlands
Flow path at least 1:1	Flow path at least 1:5 to 1
Average ED time of 24 hours or less	Average ED time of 36 hours
No maximum vertical ED limit	Maximum vertical ED limit of 4 feet
Turf Cover on Floor	Trees and wetlands in the planting plan
Single cell (i.e., no forebay and micropool)	Multiple cells or treatment methods (e.g., sand filter or biotretention on pond floor)
Sizing: Level 1: 2% of CDA **Level 2:** 4% of CDA	

Table 8 Wet Pond Design Guidance	
Level 1 Design (RR: 0 TP: 50)	**Level 2 Design (RR: 0 TP: 75)**
TV= (Rv)(A) (1")/12	TV = 1.5(Rv) (A) (1")/12
Single Pond Cell, with Forebay	Wet ED or Multiple Cell Design
Pool Depth Range of 3 to 12 feet	Pool Depth Range of 4 to 8 feet
Flow path 1:1 or less	Flow path 1.5:1 or more
Pond intersects with groundwater	Adequate Water Balance
Sizing: Level 1: 3% of CDA **Level 2:** 5% of CDA	

Table 8 Constructed Wetland Design Guidance	
Level 1 Design (RR: 0 TP: 50)	**Level 2 Design (RR: 0 TP:75)**
TV= (Rv)(A) (1")/12	TV = 1.5(Rv) (A) (1")/12
Single cell (with forebay)	Multiple cells
ED wetland	No ED in wetland
Uniform wetland depth	Diverse microtopography
Flow path 1:1 or less	Flow path 1.5:1 or more
Emergent wetland design	Wooded wetland design
Sizing: Level 1: 3% of CDA **Level 2:** 5% of CDA	

Table 9 Green Roof Design Guidance	
Level 1 Design (RR: 45 TP: 0)	**Level 2 Design (RR: 60 TP: 0)**
Depth of media four to six inches	Media depth greater than six inches
Soil media not tested for P-index	Soil media with P index less than 10
Green roof receives roof runoff	Green roof does not receive roof runoff or is designed with additional media depth
Sizing: Level 1: 0% of CDA **Level 2:** 10% of CDA	

Table 10 Pervious Parking Design Guidance	
Level 1 Design (RR: 45 TP: 25)	**Level 2 Design (RR: 75 TP: 25)**
TV= (Rv)(A) (1")/12	TV = 1.1(Rv) (A) (1")/12
Soil Infiltration less than one-inch/hr	Soil infiltration rate exceeds one-inch/hr
Underdrain needed	Underdrain not required
Accepts runoff from non-pervious pavement	CDA = The pervious paver area
Slopes from 2 to 5%	Slopes less than 2%
Sizing: Level 1: 0% of CDA **Level 2:** 0% of CDA	

Table 11 Rain Tanks and Cisterns
RR 15% for seasonal irrigation reuse and **RR 65%** for internal dual use **PR= 0**
Assume tanks consume 5% of building area.

Table 12 Sheetflow to Conserved Open Space
RR: 75% for A and B Soils **RR: 50%** for C and D Soils **PR: O**
Conservation Area must be at least 0.5 acres in size and protected by easement
Maximum contributing sheet flow path from adjacent pervious areas is 150 feet
Maximum contributing sheet flow path from adjacent impervious areas is 75 feet
Slopes cannot be steeper than 3%

Table 13 Simple Rooftop Disconnection
RR: 50% for A and B Soils **RR: 25%** for C and D Soils **PR: O**
Only allowed for residential lots greater than 6000 square feet
Rooftop area draining to any single discharge point should not exceed 1000 sf and drain continuously through pervious filter until reaching property line ort drainage swale
Slope should be in 1 to 2% range and not cause basement seepage

Table 14 Soil Amendments
RR: 75% for rooftop disconnection **RR: Shift to forest Rv** if combined with reforestation **RR**: Go to Level 2 if RR added to grass or dry swale
Amended soils to a foot depth; should be sized at 50% of CDAa

Table 15 Disconenct to Rain Garden or Dry Well
RR: 75% for rooftop disconnection
Size either type as 10 to 15% of roof CDA

Table 16 Reforestation and Individual Trees
Reforestation RR: Shift to forest Rv if combined with soil amendments
Reforestation area must be at least 5000 square feet
Individual Trees: Assume 10 cubic feet per planted tree (for now)
Must have adequate soil volume to asure future growth