DOCUMENT C:
DOCUMENTATION FOR THE RUNOFF REDUCTION METHOD

This document contains basic methods and computations that are built into the spreadsheet procedures. It combines the process with the equations. It is intended for users who want to verify or adapt the method.

Site Data Sheet

1.A 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.

1.B Determine the Target Phosphorous Load based upon site size and location and indicate it on **line 18**.

1.C For the site, indicate post-development impervious, managed turf, and forest/open space land cover in **lines 23-25**. Guidance for various land covers is provided in Table 1.

Table 1. Land Cover Guidance for Virginia Runoff Reduction Spreadsheet
IMPERVIOUS COVER
• Roadways, driveways, rooftops, parking lots, sidewalks, and other areas of impervious cover. • This category also includes the surface area of stormwater BMPs that: (1) are wet ponds, OR (2) replace an otherwise impervious surface (e.g., green roof, pervious parking).[1]
MANAGED TURF
Land disturbed and/or graded for eventual use as managed turf: • Portions of residential yards that are graded or disturbed, including yard areas, septic fields, residential utility connections • Roadway rights-of-way that will be mowed and maintained as turf • Turf areas intended to be mowed and maintained as turf within residential, commercial, industrial, and institutional settings
FOREST & OPEN SPACE
Land that will remain undisturbed OR that will be restored to a hydrologically functional state: • Portions of residential yards that will NOT be disturbed during construction • Portions of roadway rights-of-way that, following construction, will be used as filter strips, grass channels, or stormwater treatment areas; MUST include soil restoration or placement of engineered soil mix as per the design specifications • Community open space areas that will not be mowed routinely, but left in a natural vegetated state (can include areas that will be bush hogged no more than four times per year) • Utility rights-of-way that will be left in a natural vegetated state (can include areas that will be bush hogged no more than four times per year) • Surface area of stormwater BMPs that are NOT wet ponds, have some type of vegetative cover, and that do not replace an otherwise impervious surface. BMPs in this category include bioretention, dry swale, grass channel, ED pond that is not mowed routinely. stormwater wetland, soil amended areas that are vegetated, and infiltration practices that have a vegetated cover. • Other areas of existing forest and/or open space that will be protected during construction and that will remain undisturbed

Operational & Management Conditions for Land Cover in Forest & Open Space Category:

- Undisturbed portions of yards, community open space, and other areas that will be considered as forest/open space must be shown outside the LOD on approved E&S plans AND demarcated in the field (e.g., fencing) prior to commencement of construction.
- Portions of roadway rights-of-way that will count as forest/open space are assumed to be disturbed during construction, and must follow the most recent design specifications for soil restoration and, if applicable, site reforestation, as well as other relevant specifications if the area will be used as a filter strip, grass channel, bioretention, or other BMP
- All areas that will be considered forest/open space for stormwater purposes must have documentation that prescribes that the area will remain in a natural, vegetated state. Appropriate documentation includes: subdivision covenants and restrictions, deeded operation and maintenance agreements and plans, parcel of common ownership with maintenance plan, third-party protective easement, within public right-of-way or easement with maintenance plan, or other documentation approved by the local program authority
- While the goal is to have forest/open space areas remain undisturbed, some activities may be prescribed in the appropriate documentation, as approved by the local program authority: forest management, control of invasive species, replanting and revegetation, passive recreation (e.g., trails), limited bush hogging to maintain desired vegetative community, etc.

[1] Certain stormwater BMPs are considered impervious with regard to the land cover computations. These BMPs are still assigned Runoff Reduction and/or Pollutant Removal rates within the spreadsheet, so their “values” for stormwater management are still accounted for. The reason they are considered impervious is that they either do not reduce runoff volumes (e.g., wet ponds) OR their Runoff Reduction rates are based on comparison to a more conventional land cover type (e.g., green roofs, pervious parking).

2. From the land cover input, a weighted site runoff coefficient (Rv) will be calculated (**line 47**), as will the required Post Development Treatment Volume (**lines 49-50**).

Land Cover Rv:

Rv(F) = [(A(fA) x 0.02) + (A(fB) x 0.03) + (A(fC) x 0.04) + (A(fD) x 0.05)]/SA
Rv(T) = [(A(tA) x 0.15) + (A(tB) x 0.20) + (A(tC) x 0.22) + (A(tD) x 0.25)]/SA
Rv(I) = 0.95
%Forest = (A(fA) + A(fB) + A(fC) + A(fD))/SA x 100
%Turf = (A(tA) + A(tB) + A(tC) + A(tD))/SA x 100
%Impervious = (A(iA) + A(iB) + A(iC) + A(iD))/SA x 100

Where:

Rv(F) = weighted forest runoff coefficient
A(fA) = area of post-development forest and open space in A soils (acres)
A(fB) = area of post-development forest and open space in B soils (acres)
A(fC) = area of post-development forest and open space in C soils (acres)
A(fD) = area of post-development forest and open space in D soils (acres)

Rv(T) = weighted turf runoff coefficient
A(tA) = area of post-development managed turf in A soils (acres)
A(tB) = area of post-development managed turf in B soils (acres)
A(tC) = area of post-development managed turf in C soils (acres)
A(tD) = area of post-development managed turf in D soils (acres)

Rv(I) = weighted impervious cover runoff coefficient
A(iA) = area of post-development impervious cover in A soils (acres)

A(iB) = area of post-development impervious cover in B soils (acres)
A(iC) = area of post-development impervious cover in C soils (acres)
A(iD) = area of post-development impervious cover in D soils (acres)

SA = total site area (acres)

Site Rv:
Rv(S) = Rv(F) x %Forest + Rv(T) x %Turf +Rv(I) x %Impervious

Where:
Rv(S) = runoff coefficient for the site
Rv(F) = weighted forest runoff coefficient
Rv(T) = weighted turf runoff coefficient
Rv(I) = weighted impervious cover runoff coefficient

Post Development Treatment Volume:
Tv(S) = Rd x Rv(S) x SA/12 – Rd x Rv(F) x A(f)/12

Where:
Tv(S) = post-development treatment volume for site (acre-ft)
Rd = rainfall depth for target event (1" for water quality storm)
Rv(S) = runoff coefficient for the site
SA = total site area (acres)
Rv(F) = weighted forest runoff coefficient
A(f) = total area of forest and open space

3. A Post Development TP Load, and the required TP load reduction will be calculated based upon the Post Development Treatment Volume (**lines 51-52**).

Post Development TP Load
$L = P \times P_j \times [Tv(S)/Rd] \times C \times 2.72$

Where:
L = post-development pollutant load for site (pounds / year of total phosphorus)
P = average annual rainfall depth (inches) = 43 inches for Virginia
P_j = fraction of rainfall events that produce runoff = 0.9
Tv(S) = post-development treatment volume for site (acre-ft)
Rd = rainfall depth for target event (1" for water quality storm)
C = flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.26 mg/L for total phosphorus
2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters

Required TP Load Reduction
Lreduction = L – Ptarget x SA

Where:
Lreduction = required TP Load Reduction (pounds / year of total phosphorous
L = post-development pollutant load for site (pounds / year of total phosphorus)
Ptarget = Target phosphorous load (pounds / acre / year)
SA = total site area (acres)

D.A. A

1. If the site has multiple discharge points, or complex treatment sequences, it may be beneficial to divide the site into more than one drainage area. Indicate the post-

development impervious, managed turf, and forest/open space land cover for Drainage Area A in **lines 11-13**.

5.1.A. Apply Runoff Reduction (RR) Practices to the drainage area to reduce post-development treatment volume and load by indicating in **column G** the number of acres to be treated by a given RR practice. Note that some RR practices are divided into turf area and impervious area to be treated. 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. The available RR Practices include:

- Green roof
- Impervious surface disconnection
- Permeable pavement
- Grass channel
- Dry swale
- Bioretention
- Wet swale
- Infiltration
- Extended detention pond
- Sheetflow to conservation area or filter strip

5.1.B. Based upon the runoff reduction capability of the selected BMP, the spreadsheet will calculate the Runoff Reduction Volume in **column I** and the Remaining Runoff Volume in **column J.**

Adjustment to Treatment Volume
Cv(x) = (Rd x Rv(land cover) x CA x 3630 + Vupstream) x CR

Where:
Cv(x) = Adjustment to treatment volume based on application of credit X (cubic feet)
Rd = rainfall depth for target event (1" for water quality storm)
Rv(land cover) = weighted runoff coefficient for land cover being treated by credit practice (impervious or managed turf)
CA = area credit applied to (acres)
3630 = unit adjustment factor, converting acre-inches to cubic feet
Vupstream = Upstream runoff volume directed to credit practice
CR = credit (fraction of runoff eliminated by the credit practice)

5.1.C. These practices also have a pollutant removal efficiency (**column K**), which will be applied to the remaining runoff volume (after runoff reduction has been applied). The spreadsheet will calculate the adjustment to the phosphorus load in **column N**:

Pollutant Load to the Practice

L(x) = Lupstream+ [Rv(land cover) x CAxPx Pi/12 -CV(x)/43,560]x2.72xEMC

Where:

L(x) = Pollutant Load to the Practice (pounds/yr)
Lupstream = Pollutant load from upstream treatment practices
Rv(land cover) = weighted runoff coefficient for land cover being treated by credit practice (impervious or managed turf)
CA = area credit applied to (acres)
P = average annual rainfall depth (inches) = 43 inches for Virginia
Pj = fraction of rainfall events that produce runoff = 0.9
12 = unit adjustment factor, converting acre-inches to acre-ft
43,560 = unit adjustment factor, cubic feet to acre-ft
Cv(x) = adjustment to treatment volume based on application of BMP credit (cubic ft)
EMC = flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.26 mg/L for total phosphorus
2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters

Pollutant Removal (or Load Reduction)

$LR(x) = L(x)*[Cv(x)+ ATv(x)* EFF_{TP} / 100]/[Cv(x)+ATv(x)]$

Where:

LR(x) = Load Reduction (lbs/year)
L(x) = Load to the practice (lbs/year)
Cv(x) = Cv(x) = adjustment to treatment volume based on application of BMP credit (cubic ft)
ATv(x) = Remaning Runoff Volume after credit X is applied (cubic feet) (See 5.2A below)
EFF_{TP} = Total Phosphorus pollutant removal efficiency
100 = % conversion factor

5.2.A. If a secondary RR practice or a pollutant removal practice will be utilized in sequence downstream of the primary RR practice (for example, 2 acres of impervious rooftop are to be treated first with a green roof, and then, after discharge from the roof, will be conveyed via a dry swale), select the downstream RR practice from the pull-down menu in **column P** (click on the blue box in column P to see the pull-down menu). The spreadsheet will calculate the Remaining Runoff Volume and then direct it to the selected downstream RR practice via **column H**, and the remaining phosphorus load to **column L.** Sequences of three or more practices can be accommodated as well.

Remaining Runoff Volume

ATv(x) = (Rd x Rv(land cover) x CA x 3630 + Vupstream) x (1-CR)

Where:

ATv(x) = Remaning Runoff Volume after credit X is applied (cubic feet)
Rd = rainfall depth for target event (1" for water quality storm)
Rv(land cover) = weighted runoff coefficient for land cover being treated by credit practice (impervious or managed turf)
CA = area credit applied to (acres)
3630 = unit adjustment factor, converting acre-inches to cubic feet
Vupstream = Upstream runoff volume directed to credit practice
CR = credit (fraction of runoff eliminated by the credit practice)

Remaining Phosphorus Load

AL(x) = L(x) – LR(x)

Where:

AL(x)	=	Remaining Phosphorus Load after treatment by the practice (lb/year)
L(x)	=	Load to the practice (lbs/year)
LR(x)	=	Load Reduction (lbs/year)

5.2.B. Select all the RR practices that will be used for the drainage area. Note that it is possible for a RR practice to be a downstream practice for one area, and a primary practice for another (Using the example above, a dry swale can receive discharge from a green roof and can also receive runoff directly from an impervious parking area.). It is also possible for more than one primary practice to be directed to the same downstream practice. However, the spreadsheet will not allow runoff from one primary practice to be diverted into two different downstream practices. If a site design calls for this, the site will need to be divided into separate drainage areas, or the design worksheet may be utilized instead of the spreadsheet.

5.3.A. From the selected RR practices, the total runoff reduction will be calculated on **line 80**, along with the TP load reduction achieved on **line 81.**

Total Adjustment to Treatment Volume

$Cv = \sum Cv(x)$

Where:

Cv	=	total adjustment to treatment volume for the drainage area through application of runoff reduction credits (cubic ft)
Cv(x)	=	Adjustment to treatment volume based on application of credit X (cubic feet)

Total Load Reduction Achieved

$LR_{RR} = \sum LR(x)$

LR_{RR} = Load Reduction achieved by Runoff Reduction Measures

LR(x) = Pollutant Removal Achieved by individual runoff reduction practice (pounds)

5.3.B. The phosphorous load calculations on lines 80 and 81 account for both the runoff reduction and pollutant removal achieved by runoff reduction practices. Additional practices, such as filters, ponds and wetlands remove phosphorous from runoff via settling, filtering, biological uptake, and other processes, but do not achieve runoff reductions. These practices should be viewed as supplemental to runoff reduction measures. **Lines 86-118** account for pollutant removal from practices that do not provide runoff reduction. Indicate acres of turf or impervious cover that drain to these practices *without* first being treated by another practice in **Column D.** The remaining phosphorus load and (unchanged) runoff volume can then be directed to a downstream practice chosen in **Column K.** Runoff volume and phosphorus load from upstream practices are included **Columns F and G**, respectively, for these practices.

5.3.C. The TP load reduction for the practices on lines 86-118 are calculated in **Column I** and summed on **cell I120**. This load is added to the phosphorus removal achieved by upstream runoff reduction practices and totaled in **cell I121.**

Phosphorous Load Reduction

$LR(x) = [Lupstream+P \times Pi \times Rv(land\ cover) \times A/12 \times EMC \times 2.72] \times EFF_{TP} / 100$

Where:

LR(x) = Pollutant Removal Achieved by individual BMP (pounds)
Lupstream = Phosphorus Load from upstream practices
P = average annual rainfall depth (inches) = 43 inches for Virginia
Rv(land cover) = weighted runoff coefficient for land cover being treated by the BMP
A = Area draining to the practice (acres)
EMC = flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.26 mg/L for total phosphorus
12 = unit adjustment factor, converting acre-inches to acre-ft
2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters
EFF_{TP} = Total Phosphorus pollutant removal efficiency
100 = % conversion factor

Total Phosphorous Load Reduction

$LR = \sum LR(x) + LR_{RR}$

Where:

LR = Total Pollutant Removal Achieved (pounds / year of total phosphorous)
LR(x) = Pollutant Removal Achieved by individual BMP (pounds / year of total phosphorous)
LR_{RR} = Load Reduction achieved by Runoff Reduction Measures (lbs/year)

D.A. B – D.A. E

If there is only one drainage area for the site, sheet D.A. B, C, D, and E should be left blank. If there is more than one Drainage area, fill out these tabs in the same manner as D.A. A.

Water Quality Compliance

6. The water quality compliance sheet summarizes the runoff reduction and pollutant removal results for the site. **Line 11** will indicate if additional TP load needs to be removed. If there is still a TP load to remove after applying runoff reduction and pollutant removal practices on D.A. A – D.A. E, the site should be reconfigured to reduce impervious or turf areas, or additional RR practices and pollutant removal practices must be selected on sheets D.A. A – D.A. E.

Channel and Flood Protection

This sheet assists with calculation of Adjusted Curve Numbers that can be used to calculate the channel protection and flood control volumes necessary for the site.

7. Compare the site area to the total watershed area draining to the point of discharge, and the post-development peak flow from the site for the 1-year storm (see steps 8.A-D below) to the 1-year storm peak flow for the total watershed area draining to the point of discharge. If the site area is less than one percent of the watershed area, or the 1-year post-development peak flow is less than one percent

of the watershed peak flow at the point of discharge, channel protection and flood protection requirements do not apply.

8.A Indicate the appropriate regional depths for the 1-year, 2-year, and 10-year 24-hour storms on **Line 2**.

8.B Each land cover and soil type is associated with a Natural Resource Conservation Service (NRCS) curve number. Using these curve numbers, a weighted curve number and the total runoff volume for each drainage area is calculated. For Drainage Area A, **Line 37** calculates the runoff volume without regard to the RR practices employed on the site. **Lines 38** subtracts the volume treated by the RR practices from these totals. The spreadsheet then determines the curve number that results in the calculated runoff volume with RR practices. This Adjusted Curve Number is reported on **line 39.**

These steps are repeated for Drainage Areas B – E.

Weighted Curve Number

CN = [(A(fA) x 30) + (A(fB) x 55) + (A(fC) x 70) + (A(fD) x 77)+ (A(tA) x 39) + (A(tB) x 61) + (A(tC) x 74) + (A(tD) x 80) + A(iA) x 98) + (A(iB) x 98) + (A(iC) x 98) + (A(iD) x 98)]/DA

Where:

CN = weighted curve number
A(fA) = area of post-development preserved or restored forest in A soils (acres)
A(fB) = area of post-development preserved or restored forest in B soils (acres)
A(fC) = area of post-development preserved or restored forest in C soils (acres)
A(fD) = area of post-development preserved or restored forest in D soils (acres)

A(tA) = area of post-development managed turf in A soils (acres)
A(tB) = area of post-development managed turf in B soils (acres)
A(tC) = area of post-development managed turf in C soils (acres)
A(tD) = area of post-development managed turf in D soils (acres)

A(iA) = area of post-development impervious cover in A soils (acres)
A(iB) = area of post-development impervious cover in B soils (acres)
A(iC) = area of post-development impervious cover in C soils (acres)
A(iD) = area of post-development impervious cover in D soils (acres)

DA = Drainage Area (acres)

Potential Abstraction

S = 1000/(CN-10)

Where:

S = Potential Abstraction (inches)
CN = weighted curve number

Runoff Volume with no Runoff Reduction

$V = (P - 0.2 \times S)^2 / (P + 0.8 \times S)$

Where:

V = Runoff volume with no runoff reduction (inches)

P	=	Precipitation depth for a given 24-hour storm (inches)
S	=	Potential Abstraction (inches)

Runoff Volume with Runoff Reduction

V_{rr} = V – (Cv(da) / 3630 / DA

Where:

Vrr	=	Runoff volume with runoff reduction (inches)
Cv(da)	=	total adjustment to treatment volume for the drainage area through application of runoff reduction credits (cubic ft)
3630	=	unit adjustment factor, cubic feet to acre-inches
DA	=	drainage area (acres)

Adjusted Curve Number:

The adjusted curve number is calculated using a lookup table of curve number and runoff volumes so that:

$CN_{adjusted}$, so $(P-0.2 \times S_{adjusted})^2 / (P + 0.8 \times S_{adjusted}) = V_{rr}$

$S_{adjusted} = 1000/(CN_{adjusted} - 10)$

Where:

$CN_{adjusted}$	=	Adjusted curve number that will create a runoff volume equal to the drainage area runoff volume including runoff reduction practices
P	=	Precipitation depth for a given 24-hour storm (inches)
$S_{adjusted}$	=	Adjusted potential abstraction based upon adjusted curve number (inches)
Vrr	=	Runoff volume with runoff reduction (inches)

Channel Protection Conditions

Detention or other means may be necessary to reduce the developed peak runoff to the allowable peak runoff values described below. Note that if, on sheets D.A. A – E, Extended Detention, Constructed Wetlands, or Wet Ponds are utilized, there may already be detention volume available to meet these requirements. Actual storage designed in the facility should be accounted for to calculate detention provided. Storage designed into bioretention, permeable pavement, or other practices can also be used to meet detention requirements where the applicant can demonstrate to the approval authority that the practice meets partial or complete detention requirements above and beyond the sizing required for water quality treatment.

9.A To meet condition 1, demonstrate that the developed peak runoff from the 2-year 24-hour storm is conveyed without causing erosion of the system.

9.B To meet condition 2, demonstrate that the runoff from the developed site, in combination with other existing stormwater runoff, will not exceed the design of the restored stormwater conveyance system nor result in instability of the system.

9.C To meet condition 3, the maximum allowable peak runoff from the 1-year storm is equal to the following:

Maximum Peak Flow

$\text{Allowable } Q_{Developed} = Q_{Pre\text{-}Developed} \times RV_{Pre\text{-}Developed} / RV_{Developed}$

Where:

Allowable $Q_{Developed}$ = the maximum allowable peak flow from the site to meet condition 3 (cubic feet per second)

$Q_{Pre\text{-}Developed}$ = peak runoff rate for the drainage area in the pre-developed condition (cubic feet per second)

$RV_{Pre\text{-}Developed}$ = Runoff volume for the pre-developed condition (inches)

$RV_{Developed}$ = Post-development runoff volume with runoff reduction (inches)

9.D To meet condition 4, the maximum allowable peak runoff from the 1-year storm is equal to the following:

Maximum Peak Flow

$\text{Allowable } Q_{Developed} = Q_{Good\ Pasture} \times RV_{Good\ Pasture} / RV_{Developed}$

Where:

Allowable $Q_{Developed}$ = the maximum allowable peak flow from the site to meet condition 4 (cubic feet per second)

$Q_{Good\ Pasture}$ = peak runoff rate for the drainage area in the good pasture condition (cubic feet per second)

$RV_{Good\ Pasture}$ = Runoff volume for the good pasture condition (inches)

$RV_{Developed}$ = Post-development runoff volume with runoff reduction (inches)

Flood Control Conditions

Detention or other means may be necessary to reduce the developed peak runoff to the allowable peak runoff values described below. Note that if, on sheets D.A. A – E, Extended Detention, Constructed Wetlands, or Wet Ponds are utilized, there may already be detention volume available to meet these requirements. Actual storage designed in the facility should be accounted for to calculate detention provided. Storage designed into bioretention, permeable pavement, or other practices can also be used to meet detention requirements where the applicant can demonstrate to the approval authority that the practice meets partial or complete detention requirements above and beyond the sizing required for water quality treatment.

10. Using the calculations under 8.A through 8.B above, determine the peak discharge rates for the relevant water flood control storms.

11.A. To meet conditions 1, 2, or 3, demonstrate that the developed peak runoff from the 10-year 24-hour storm is confined within the man-made conveyance system.

11.B. To meet condition 4, the maximum allowable peak runoff from the 10-year 24-hour storm must be equal to the peak runoff from the site in a good pasture condition

11.C Condition 5 is dependent upon local determination,