VIRGINIA RUNOFF REDUCTION METHOD
Compliance Spreadsheet User's Guide & Documentation
(April, 2012 Version 2.5)

Table of Contents

1.0 INTRODUCTION

Virginia's proposed Stormwater Management Program (VSMP) Permit Regulations (4 VAC 50-60 et al) include water quality and quantity requirements based, in part, on the "Virginia Runoff Reduction Method" (VRRM). This method is supported by recent stormwater research findings on the combined runoff volume reduction and pollutant removal performance of various stormwater best management practices (BMPs). More information and documentation on the development and the basis of the VRRM can be found in the Technical Memorandum, dated April 18, 2008 (CWP 2008) prepared by the Center for Watershed Protection and the Chesapeake Stormwater Network. The memorandum can be downloaded from the DCR Stormwater Program website.

The VRRM is accompanied by a compliance spreadsheet. The spreadsheet is designed to help designers and plan reviewers to quickly evaluate the implementation of BMPs on a given site and verify compliance with the local and/or State stormwater requirements. The spreadsheet:

- Provides a summary of the total site developed condition land cover, pollutant load (Total Phosphorus and Total Nitrogen), and the corresponding design Treatment Volume.
- Allows the designer to quickly evaluate the effectiveness of different BMPs and BMP combinations in up to five different drainage areas.
- Provides a summary for each drainage area that includes the land cover, runoff volume and pollutant load generated in the drainage area, the BMPs selected, and the runoff volume and pollutant load reduced by the selected BMPs.
- Calculates the volume reduction credited towards compliance with quantity control requirements in each drainage area (i.e., channel and flood protection requirements).
- Provides an overall compliance summary report that itemizes BMP implementation in each drainage area as well as overall site compliance.

> **NOTE:** *The RRM compliance spreadsheet is not a BMP design tool. When a BMP is selected in the spreadsheet, it is assumed that the designer will locate and design the BMP according to the design criteria provided in the Virginia BMP Design Specifications. Please refer to the Virginia BMP Clearinghouse website for the latest BMP design criteria.*

Using this Guide: It is recommended that the user review this information with the spreadsheet open on your computer.

2.0 VRRM COMPLIANCE SPREADSHEET BASICS

The VRRM Compliance Spreadsheet includes several terms that may or may not be exactly consistent with definitions in the regulations. The following provides a listing of important terms by spreadsheet tab, and a basic definition of how the term is applied in the VRRM compliance spreadsheet.

2.1 Site Data Tab

Figure 1 provides a screen shot of the Site Data tab.

Annual Rainfall is a user defined value that may vary across Virginia. (Refer to the Virginia Stormwater Management Handbook (VSMH) for appropriate values).

Target Rainfall Event is defined as the one-inch rainfall depth (as determined to be the 90^{th} percentile annual rainfall depth).

Phosphorus EMC (mg/l) and **Nitrogen EMC** are the Event Mean Concentrations of Total Phosphorus and Total Nitrogen, respectively, in urban runoff. This value is based on an extensive review of monitoring data in Virginia. (CWP 2008)

Target Phosphorus Load (lb/ac/yr) is the load limit established by the VSMP Permit Regulations.

Land Cover (acres) includes the three basic categories of developed land: *Forest/Open Space*, *Managed Turf*, or *Impervious cover.* Definitions of the three categories of land cover and the basic qualifications for each is provided in **Section 3.2**, **Table 1** of this Guide). The acreages of each land cover are entered by the user for the entire site on the Site Data Tab.

> **NOTE:** *The preservation of existing natural features such as highly permeable soils, wooded areas, natural flow paths, etc., are generally considered self crediting in terms of generating the developed condition hydrology, treatment volume, and runoff peak flow rates. However, some of these same features can also be utilized as runoff reduction BMPs to either reduce the runoff volume that would otherwise be generated by disturbing or converting the land, or by directing runoff from developed areas to the undisturbed open space to achieve runoff volume reduction. Refer to* ***Table 1*** *for the definitions of the three land cover categories. It is important that the appropriate land cover be entered on the Site Data Tab as well as the individual drainage area tabs to ensure accurate computation of runoff volume and pollutant load.*

Rv Coefficients are the unit less volumetric runoff coefficients that represent the runoff potential of the different land cover and soil types (Hydrologic Soil Groups A, B, C, and D).

Land Cover Summary cells represent the summary of the calculations to determine the weighted land cover Rv. The weighted Rv is provided for each land cover based on soil type (**Equation 1**).

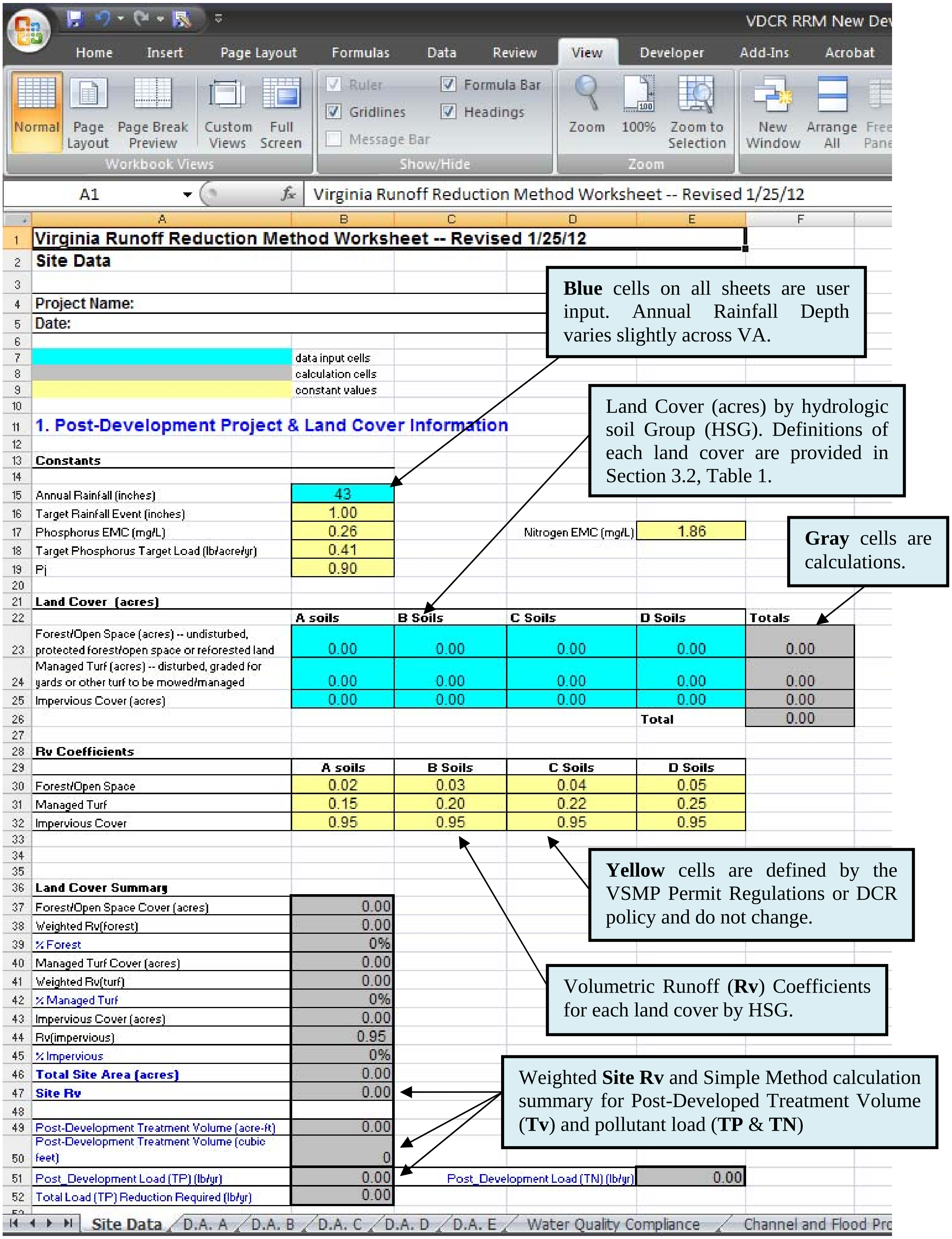

Figure 1. Site Data Tab

Site Rv is the weighted Rv Coefficient for the entire site based on the area entered for each land cover and each soil type (**Equation 2)**.

Post Development Treatment Volume is the design volume of runoff in acre-feet and cubic feet resulting from the *Target Rainfall Event.* (**Equation 3**).

Post Development Load (TP & TN)(lb/yr) is the calculated load of Total Phosphorus and Total Nitrogen for the entire site calculated using the Simple Method. (**Equation 4**).

Total Load (TP) Reduction Required (lb/yr) is the difference between the site's calculated TP and TN load and that represented by the load limit of 0.41 lb/ac/yr. Only the TP load reduction is calculated since TP is the regulatory requirement.

2.2 Drainage Area (D.A). Tabs

Figure 2 shows a screen shot of the top portion of the Drainage Area tab, and **Figure 3** shows a lower portion with the Area Check and the pollutant and volume reductions achieved in the drainage area..

The VRRM compliance spreadsheet Drainage Area tabs A through E are identical. Each provides a table near the top of the sheet for the user to enter the specific **Land Cover** acreage by soil type for the drainage area. This table computes a weighted drainage area land cover Rv, and the Post Developed Treatment Volume (Tv) for the drainage area.

An important feature of the Drainage Area tabs is the segregation of the BMPs into two groups:

- **Runoff Reduction Practices to Reduce Treatment Volume & Post-Development Load**, and
- **Practices that Remove Pollutants but Do Not Reduce Runoff Volume**.

As documented in the VRRM Technical Memorandum (CWP 2008), certain BMPs are effective at reducing both runoff volume and the pollutant concentration in the remaining runoff. Since the most cost effective application of BMPs is to utilize these dual function BMPs, the VRRM compliance spreadsheet displays the table of these BMPs first.

The Runoff Reduction BMPs listed on the website in the order they appear on the spreadsheet are:

1. Vegetated Roof (BMP Design Specification No. 5)
    a. Vegetated roof # 1
    b. Vegetated roof # 2
2. Rooftop Disconnection (BMP Design Specification No. 1)
    a. Simple Disconnection to A/B soils
    b. Simple Disconnection to C/D soils
    c. Alternative Practice Disconnection to C/D soils with Soil Amended Filter Path
    d. Alternative Practice Disconnection to Dry Well #1
    e. Alternative Practice Disconnection to Dry Well #2
    f. Alternative Practice Disconnection to Rain Garden #1

   g. Alternative Practice Disconnection to Rain Garden #2
   h. Alternative Practice Disconnection to Rainwater Harvesting
   i. Alternative Practice Disconnection to Stormwater Planter
3. Permeable pavement (BMP Design Specification No. 7)
   a. Permeable pavement #1
   b. Permeable pavement #2
4. Grass channel (BMP Design Specification No. 3)
   a. Grass Channel A/B Soils
   b. Grass Channel C/D Soils
   c. Grass Channel with Compost Amended Soils
5. Dry swale (BMP Design Specification No. 10)
   a. Dry swale #1
   b. Dry swale #2
6. Bioretention (BMP Design Specification No. 9)
   a. Bioretention #1
   b. Bioretention #2
7. Infiltration (BMP Design Specification No. 8)
   a. Infiltration #1
   b. Infiltration #2
8. Extended detention pond (BMP Design Specification No. 15)
   a. ED #1
   b. ED #2
9. Sheetflow to Filter/Open Space (BMP Design Specification No. 2)
   a. Sheetflow to Conservation Area with A/B Soils
   b. Sheetflow to Conservation Area with C/D Soils
   c. Sheetflow to Vegetated Filter Strip in A Soils or Compost Amended B/C/D Soils

The #1 and #2 label added to the BMP name indicates Level 1 and Level 2 BMP design standard. The Level 2 design standard is credited with a greater volume reduction or a greater pollutant removal, or both, compared to Level 1. The corresponding annual runoff volume reduction credit is provided in column F, the corresponding annual Phosphorus removal efficiency is provided in column K, and the corresponding annual Nitrogen removal efficiency is provided in Column S.

The designer should be familiar with the Level 1 and Level 2 design criteria in order to select the appropriate BMPs for the site.

> **NOTE:** *It is important to understand the design criteria associated with the Level 1 and Level 2 designations. While the Level 2 practices will provide greater load reductions, they may also require larger footprint, specific soil conditions, or other factors, that may limit their use. BMP selection and design guidance, including designated Level 1 and Level 2 criteria, can be found on the VA BMP Clearinghouse website.*

At the bottom of this table of BMPs is a summary of the total impervious and turf area treated by the volume reduction practices, along with an Area Check. The Area Check is to ensure that the total area entered as being treated doesn't exceed the total area entered into the Land Cover table at the top of the drainage area tab.

> **NOTE:** *A summary of the total runoff volume reduction (cell I77) and phosphorus removal achieved by the runoff reduction practices (cell I78) in the drainage area is provided. The total runoff volume reduction achieved is an important value as it will be used in the Channel and Flood Protection tab to compute the credit towards quantity control requirements.*

The next table includes BMPs that remove pollutants but do not reduce runoff volume:

1. Wet Swale (Coastal Plain) (BMP Design Specification No. 11)
    a. Wet Swale #1
    b. Wet Swale #2
2. Filtering Practices (BMP Design Specification No. 12)
    a. Filtering Practice #1
    b. Filtering Practice #2
3. Constructed Wetland (BMP Design Specification No. 13)
    a. Constructed Wetland #1
    b. Constructed Wetland #2
4. Wet Ponds (BMP Design Specification No. 14)
    a. Wet Pond #1
    b. Wet Pond #1 (Coastal Plain)
    c. Wet Pond #2
    d. Wet Pond #2 (Coastal Plain)
5. Manufactured BMPs

> **NOTE:** *Rainwater Harvesting and Manufactured BMPs require User Input to define the credit. Rainwater Harvesting systems are sized according to a water budget developed using the Virginia Rainwater Harvesting Spreadsheet, which calculates the annual volume reduction credit.*
>
> *Manufactured BMPs will be assigned a pollutant removal credit through the Virginia Technology Acceptance Protocol (VTAP) administered by the Virginia BMP Clearinghouse. There are no manufactured BMPs currently approved through the VA BMP Clearinghouse. Some manufactured BMPs may receive an interim "Conditional Use" pollutant removal credit. The User should check the BMP Clearinghouse website to verify the pollutant removal credit for any manufactured BMP.*

.

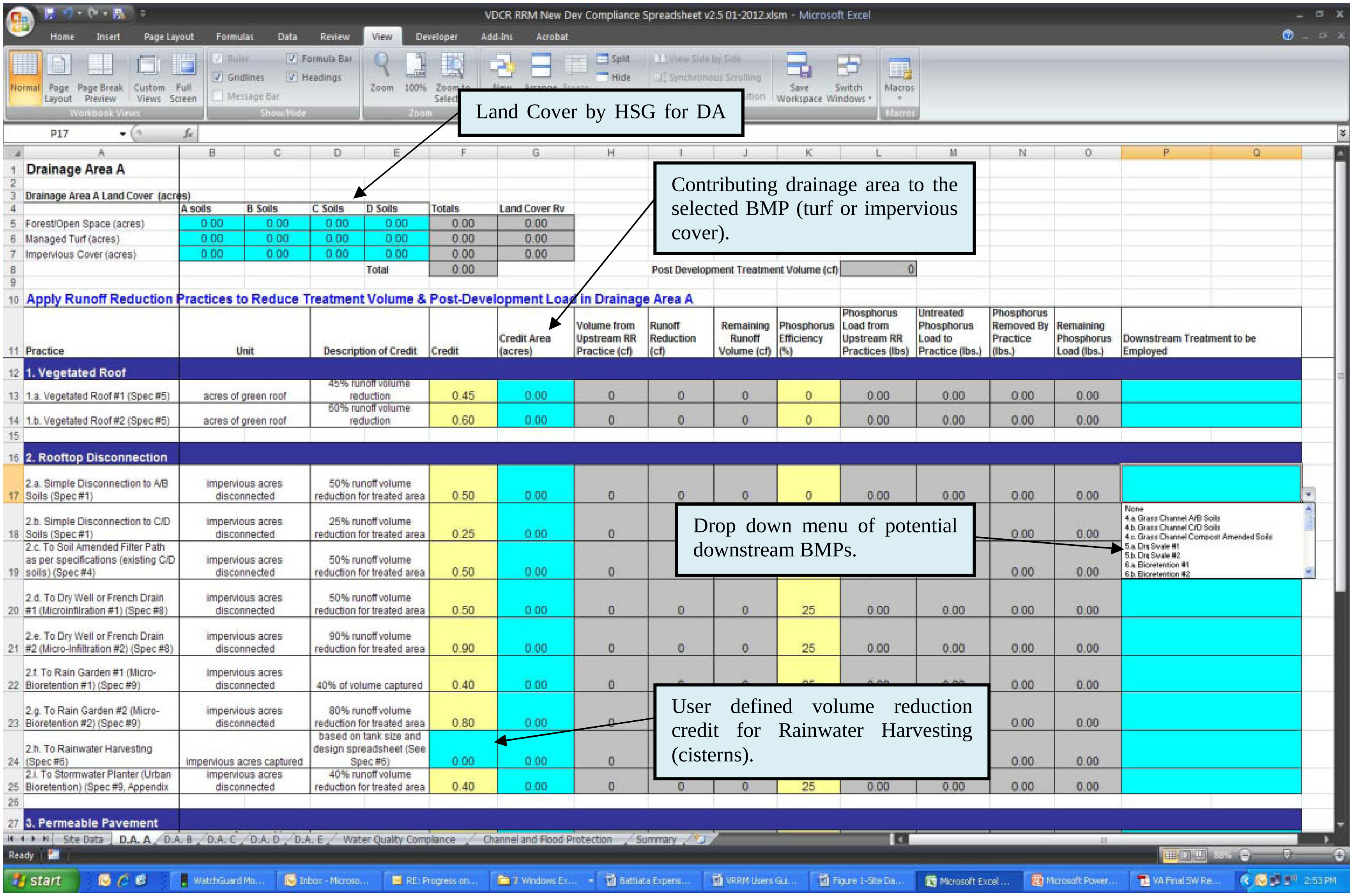

Figure 2. Top Portion of Drainage Area Tab – Volume Reduction Practices

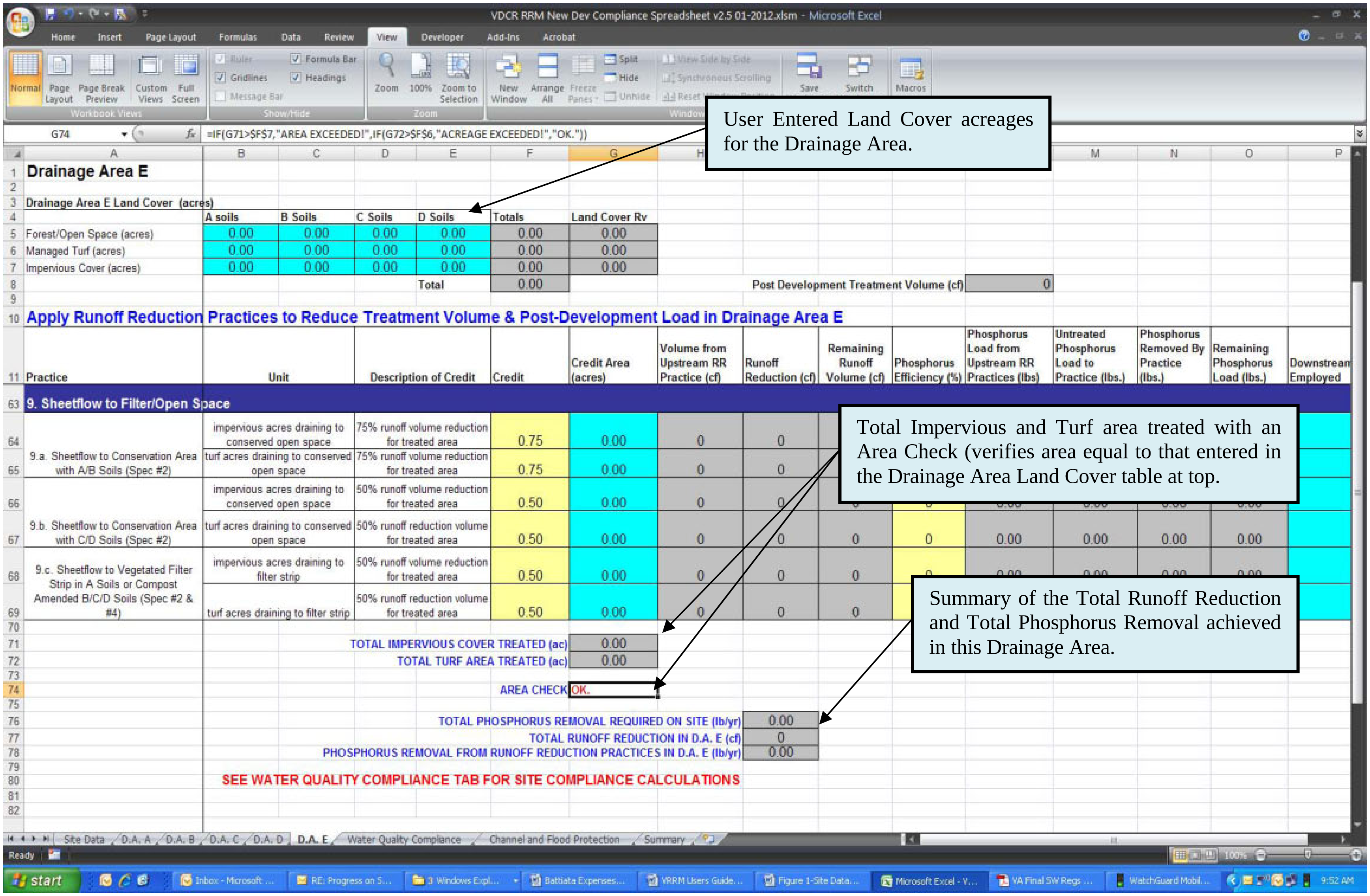

Figure 3. Lower portion of Drainage Area Tab

A summary of the impervious and turf area treated by the pollutant removal BMPs, and an Area Check is provided below this table of BMPs as well. This Area Check includes the total acreage entered for treatment, including the volume reduction BMPs. A summary of the total pollutant load reduction achieved in the drainage area is also provided. This load reduction summary represents the load reduced by both the volume reduction BMPs and the pollutant reduction BMPs. (There is no additional volume reduction achieved by these practices).

> **NOTE**: *The Total Phosphorus removal provided in the summary noted above is only that which was achieved in the drainage area. The user must proceed to the Water Quality Compliance tab in order to verify whether the selected BMP implementation through multiple drainage areas has met overall compliance.*

2.3 Water Quality Compliance Tab

The Water Quality Compliance tab summarizes the acreages of impervious cover and turf, and the corresponding acreages treated by BMPs for each Drainage Area. This also serves as an automatic **AREA CHECK**.

> **NOTE:** *The Area Check on the Water Quality Compliance tab compares the total acreages entered in each drainage area tab with the total land area entered on the Site Data tab. The Area Check on each drainage area tab compares the total acreage treated by BMPs within the drainage area with the total acreage entered for that drainage area. The Water Quality Compliance tab Area Check is important because it is possible that a user may inadvertently enter additional acreage into one or more of the DA Tabs, thereby exceeding the total acreage and resulting in increased load and/or volume reductions, or both. The Water Quality Compliance tab Area Check signals the user to verify that the Land Cover for each Drainage Area was entered into the spreadsheet accurately.*

The Water Quality Compliance tab also summarizes the Runoff Volume and Total Phosphorus load reductions achieved on the site, and indicates whether the BMP implementation in Drainage Areas A through E has met the target reductions.

Figure 4 shows the Water Quality Compliance Tab.

2.4 Channel and Flood Protection Tab

The Channel and Flood Protection Tab calculates the benefit of the runoff volume reduction when considering the larger storms required for channel and flood protection requirements. The benefit is expressed in terms of a Curve Number adjustment that can be utilized when calculating the storage volume requirements and/or the peak flow rate requirements of the VSMP Permit regulations.

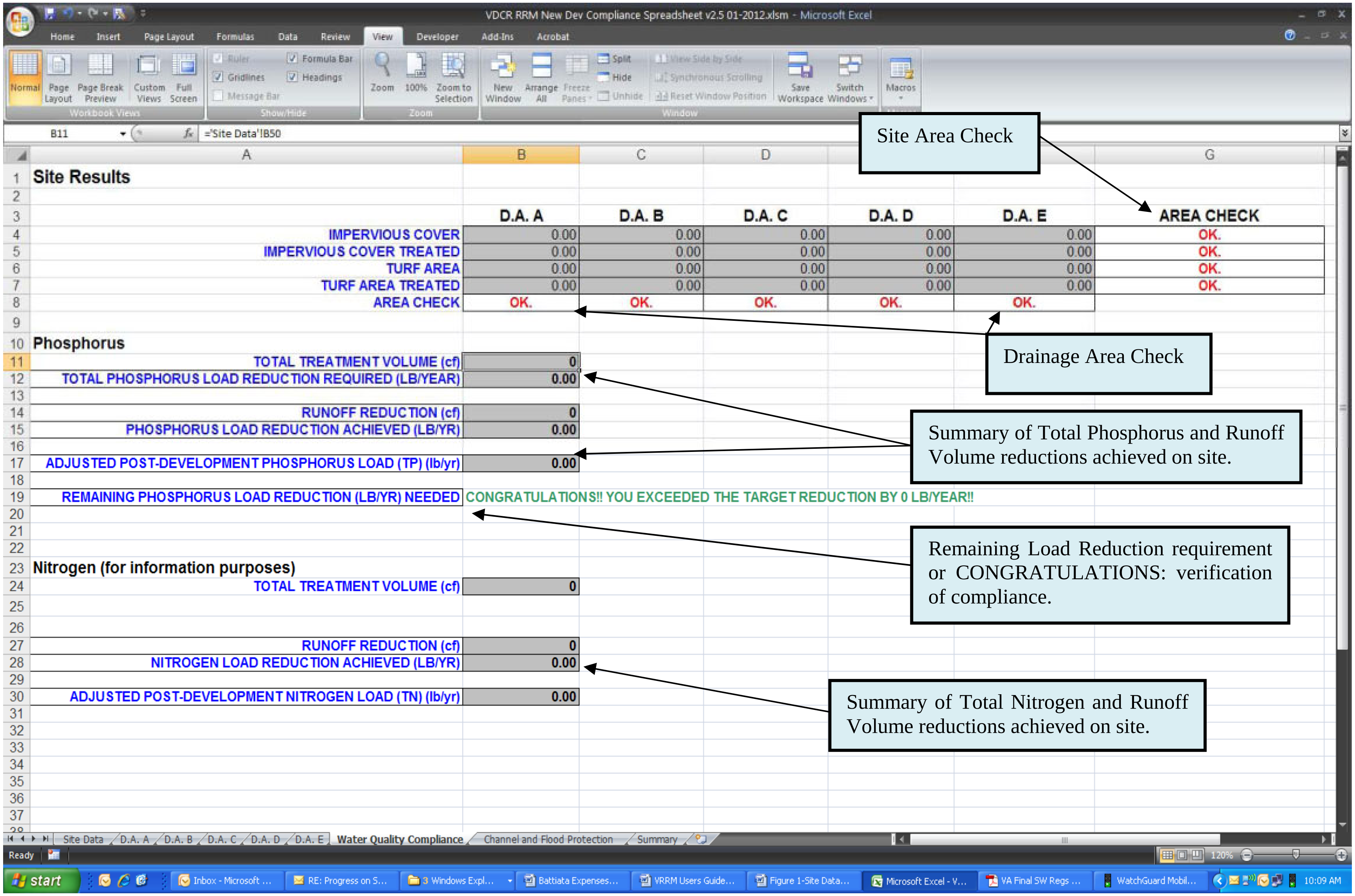

Figure 4. Water Quality Compliance Tab

The Curve Number Adjustment is based on the NRCS Runoff Equations to back calculate a new curve number for each target rainfall event based on the reduced runoff depth resulting from the retention storage. A detailed description of the method is provided in the VSMH.

This is a relatively conservative computation given that the volume reduction is considered an “annual” reduction while the Curve Number is used in “single event” modeling applications. The Curve Number adjustment is not intended to necessarily replace more rigorous single event hydrologic and hydraulic analyses of distributed practices if preferred by the site designer. However, given the complexities of such analyses, the spreadsheet’s Curve Number adjustment is considered an acceptable method for representing the annual reduction credit when designing downstream channel or flood protection structures as may be required by the VSMP Permit Regulations quantity control criteria.

> **NOTE:** *The reduced Curve Number is generally not acceptable for the design of downstream conveyance infrastructure such as roadway culverts, bridges, floodplain determinations, etc. The user should consult with VDCR or the local plan approving authority for verification of acceptable design criteria.*

Once the user has entered the appropriate **Target Rainfall Event** rainfall depth for the one-year, two-year, and/or 10-year frequency 24-hour rainfall events, the Channel and Flood Protection tab provides a summary table of the drainage area land cover acreages and the calculated weighted Curve Number (without considering the volume reduction).

Next, a table displays the Runoff Volume, **RV**, measured in watershed inches, <u>with no</u> runoff volume reduction, and the **RV** <u>with</u> runoff volume reduction.

> **NOTE:** *The value for **Rv** (unit less volumetric runoff coefficient from the Site Data tab) is different than the value for **RV** (runoff volume measured in watershed-inches):*
>
> *In the Site Data tab:*
> ***Rv** x Target Rainfall Event x Drainage Area = design Treatment Volume, Tv, in cubic feet or acre-feet for designing water quality runoff reduction BMPs.*
>
> *In the Channel and Flood Protection tab:*
> ***RV** x Target Rainfall Event = runoff volume (in watershed-inches) with which to back-calculate the Adjusted Curve Number.*
>
> *This can be confusing since common units of runoff volume are cubic inches, cubic feet, or acre-feet; however in the nomenclature of the VRRM and certain NRCS calculations, runoff is often expressed in units of watershed-inches.*

The Adjusted Curve Number is calculated for each drainage area based on the selected Target Rainfall Event and the runoff volume reduction achieved within the drainage area. **Figure 5** shows the Channel and Flood Protection Tab.

> **NOTE:** *The reduced Curve Number is generally not acceptable for the design of downstream conveyance infrastructure such as roadway culverts, bridges, floodplain determinations, etc. The user should consult with VDCR or the local plan approving authority for verification of acceptable design criteria.*

Once the user has entered the appropriate **Target Rainfall Event** rainfall depth for the one-year, two-year, and/or 10-year frequency 24-hour rainfall events, the Channel and Flood Protection tab provides a summary table of the drainage area land cover acreages and the calculated weighted Curve Number (without considering the volume reduction).

Next, a table displays the Runoff Volume, **RV**, measured in watershed inches, with no runoff volume reduction, and the **RV** with runoff volume reduction.

> **NOTE:** *The value for* ***Rv*** *(unit less volumetric runoff coefficient from the Site Data tab) is different than the value for* ***RV*** *(runoff volume measured in watershed-inches):*
>
> *In the Site Data tab:*
> ***Rv*** *x Target Rainfall Event x Drainage Area = design Treatment Volume, Tv, in cubic feet or acre-feet for designing water quality runoff reduction BMPs.*
>
> *In the Channel and Flood Protection tab:*
> ***RV*** *x Target Rainfall Event = runoff volume (in watershed-inches) with which to back-calculate the Adjusted Curve Number.*
>
> *This can be confusing since common units of runoff volume are cubic inches, cubic feet, or acre-feet; however in the nomenclature of the VRRM and certain NRCS calculations, runoff is often expressed in units of watershed-inches.*

The Adjusted Curve Number is calculated for each drainage area based on the selected Target Rainfall Event and the runoff volume reduction achieved within the drainage area.

Figure 5 shows the Channel and Flood Protection Tab.

2.5 Summary Tab

The Summary tab provides the user with a full summary of the Site Data and Drainage Area values for the purpose of generating a summary report. The user must make sure that the spreadsheet settings have been set to allow macro programs to run. The macro programs check each Drainage Area tab to identify the BMPs and BMP combinations used in each drainage area.

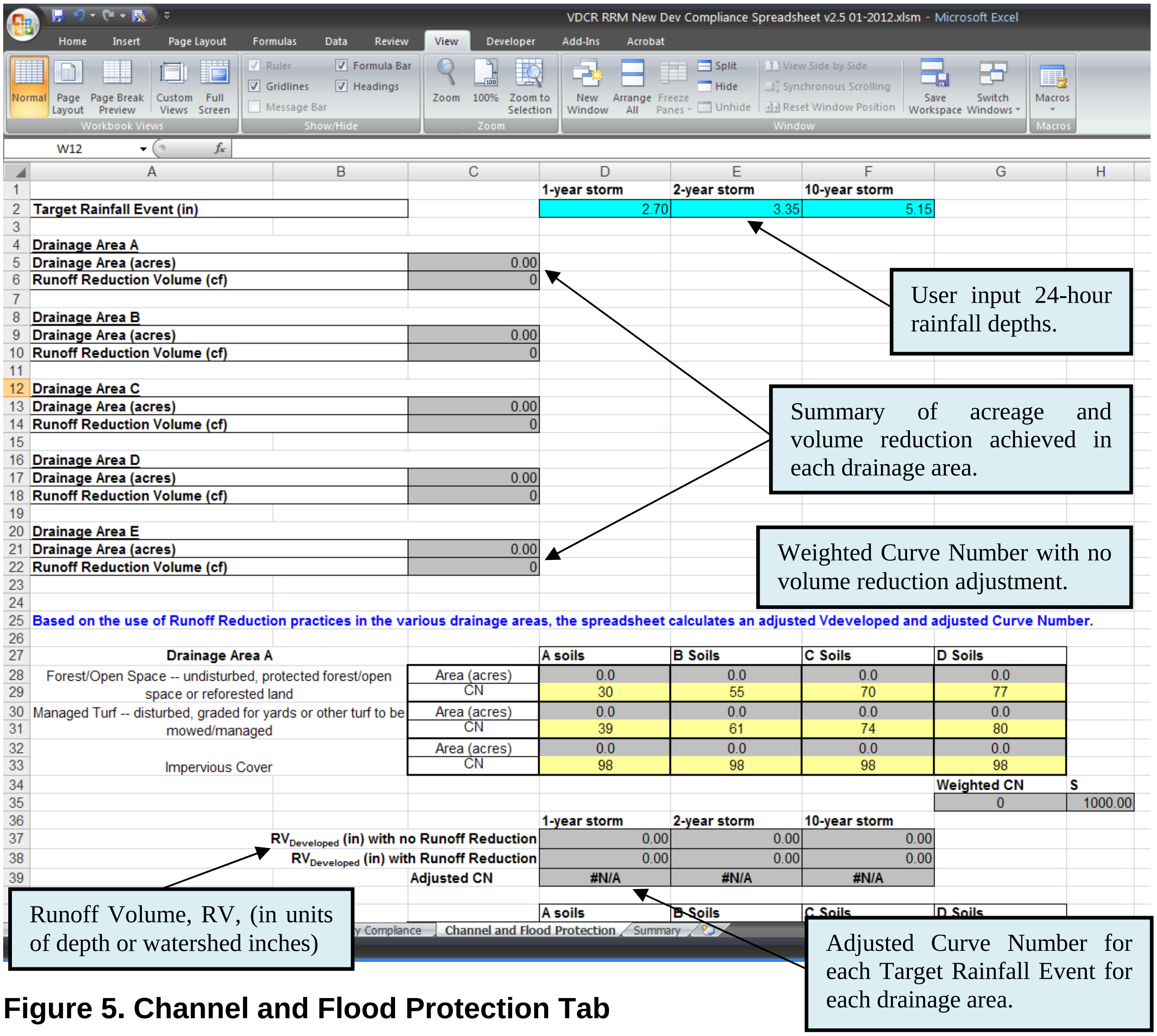

Figure 5. Channel and Flood Protection Tab

3.0 USING THE VRRM SPREADSHEET

3.1 Getting Started

These instructions generally follow the idealized process for the planning and design of a stormwater management strategy on a proposed land development project. What is not included in the spreadsheet is an emphasis on the benefit of planning the stormwater strategy early in the development process. This typically starts with the preliminary plan or other planning document that establishes the basic development footprint on the site. A designer who is familiar with the site topography, soils, vegetation, and basic hydrologic features will be able to effectively maximize runoff reduction benefits of nonstructural (and low cost) stormwater practices by utilizing Environmental Site Design (ESD) techniques.

The first step in using the VRRM Compliance Spreadsheet is to **enable macros**. This will allow the Site Data Summary to reference the Drainage Area tabs and update the summary when the design is complete.

The second important step is to be sure to “zero out” the spreadsheet. There may be values entered into miscellaneous user input cells from previous projects or trial designs that can create errors.

<u>3.2 Site Data:</u>

1. Enter the Annual Rainfall (cell B15). The accepted value of central VA is 43 inches.
2. The Target Rainfall Event, Phosphorus EMC, Target Phosphorus Load, and Pj (the fraction of annual rainfall less than 0.1”) in cells B16 through B19 are constant values.
3. Enter the Land Cover in acres for Forest/Open Space, Managed Turf, and Impervious Cover. Refer to **Table 1** for the Land Cover definitions. The total in cell F26 should be equal to the total site area.
4. The Land Cover Summary (cells B37 through B47) provides the summary values for the weighted Rv calculation for each land cover using **Equation 1a** through **1c**.
5. The Site Rv (cell B47) is the unit less weighted volumetric runoff coefficient representing the entire site. This is computed using **Equation 2**.
6. The Post Developed Treatment Volume (cell B49) in acre feet is calculated using **Equation 3**. This value multiplied by 43,560 ft^2/acre is the treatment volume in cubic feet.
7. The Post Development Total Phosphorus (TP) (cell B51) in lb/yr is the load generated by the developed condition site. This value is computed using the Simple Method and is based on the site Post Developed Treatment Volume, annual rainfall, and the TP EMC of 0.26 mg/l (**Equation 4**). A Total Nitrogen (TN) will also be calculated (cell E51) based on the TN EMC of 1.86 mg/l for informational purposes. However, compliance is based on the TP load limit only.
8. The Total TP Load Reduction Required (lb/yr) (cell B52) is the difference between the Post Developed TP Load and the site based Load Limit of 0.41 lb/ac/yr established by the VSMP Permit Regulations (**Equation 5**).

Table 1. Land Cover Guidance for VRRM Compliance 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 lots 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. These include wetlands.

<u>Operational & Management Conditions for Land Cover in Forest & Open Space Category:</u>

- 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 revegetating, 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).

3.3 Drainage Areas

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. Compliance with the water quality site based load limit is based on the entire site, meaning the sum of the treatment achieved in each drainage area must meet the total load reduction requirement noted on the site data tab. This also means that additional treatment in one drainage area may compensate for less treatment in the adjacent drainage area, with the total load reduction meeting the site requirement.

On the other hand, even a large development site can be addressed through a single BMP treatment train and may only need one drainage area tab to document the BMP strategy.

> **NOTE:** *The site based water quality requirements can be met with varying degrees of load reduction achieved in the different drainage areas. However, the quantity control requirements (channel and flood protection) must be met at each stormwater discharge or outfall from the site.*

The following discussion of the Drainage Area tab can be applied to each of the five drainage area tabs.

1. Enter the post-development forest/open space, managed turf, and impervious acreages based on hydrologic soil groups (rows 5, 6, and 7) in the drainage area. The calculation cells provide the total acreage of each land type, and the weighted Land Cover Rv (**Equation 1**).
2. Apply Runoff Reduction (RR) Practices to the drainage area to reduce post-development treatment volume and load by indicating the Credit Area (acres) in column G to be treated by a selected RR practice.
3. The user should select the practices that will be appropriate for the given site conditions (soils, drainage area, etc.) and that provide sufficient greatest volume reduction. Column F displays the constant values for the volume reduction credit.
4. The user applies practices by entering the contributing drainage area to the BMP, referred to as Credit Area (acres), in column G. This acreage input corresponds to the land cover unit as described in column B as either *impervious acres* or *turf acres*. Impervious Disconnection and Permeable Pavement only allow one option (impervious acres) due to specific design guidance that intends the practice to only treat runoff form impervious areas.
5. As the user enters acreage into the BMP Credit Area column, the spreadsheet calculates the total volume of runoff generated by the contributing drainage area (**Equation 7**). Though the value is not displayed, it is the sum of column I and column J. The next group of columns reflects data related to the runoff volume reduction as follows:
    - Column H displays the volume contributed from upstream practices if a treatment train is being used. (This is the remaining runoff volume, column

J, from any upstream practices; if no upstream practice is used, this value is zero.) More discussion on treatment trains is provided below – Step 7.

- Column I displays the total runoff volume reduction achieved by the practice (**Equation 8**). This includes the reduction as applied to the volume from the contributing drainage area, as well as a reduction in the volume coming from an upstream practice.

NOTE: *The runoff volume generated by the contributing drainage area to the practice (or the credit area – column G) is calculated using a drainage area weighted land cover Rv for turf (cell G6) rather than a soil type weighted Rv for the contributing area to the practice. The weighted impervious Rv is 0.95 regardless of soil type.*

- Column J displays the remaining runoff volume that will exit the practice (**Equation 9**). If the user chooses If the user chooses to utilize multiple BMPs in series by designating a downstream practice (column P), this value will be carried over to the volume from upstream practice (column H). (and may be directed to a downstream practice).

6. The next series of columns provides information on the pollutant removal efficiency and calculated load reduction achieved by the practice.
   - Column K provides the constant value for Phosphorus Efficiency (measured as a percent reduction of the incoming load).
   - Column L displays the phosphorus load contributed from upstream practice if a treatment train is being used. (This is the remaining phosphorus load, column O, from any upstream practices; if no upstream practice is used, this value is zero.) More discussion on treatment trains is provided in the next step.
   - Column M is the Untreated Phosphorus Load to the Practice. This is the calculated load generated by the contributing drainage area (or credit area) using the Simple Method (**Equation 10)**, plus the untreated load from the upstream practice.
   - Column N is the total Phosphorus Load Removed by the Practice. This removal is the combined load reduction resulting from the volume reduction and the pollutant removal.
   - Column O is the Remaining Phosphorus Load. If the user chooses to utilize multiple BMPs in series by designating a downstream practice (column P), this value will be carried over to the load contributed from upstream practice (column L).

NOTE: *The corresponding nitrogen pollutant load and load reductions are calculated using the same equations and the nitrogen EMC of 1.86 mg/l. The nitrogen reduction performance credit constant is column S, the nitrogen load from upstream practices is column T, the untreated load* *generated by the contributing drainage area is column U, and the nitrogen removed by the practice is column W.*

7. The user can select multiple BMPs in a treatment train. Column P provides a pull down menu of BMPs that are acceptable as a downstream practice. The spreadsheet automatically passes the remaining runoff volume and pollutant load to the selected downstream practice in the treatment train.

   When selecting downstream BMPs in a treatment train, the entire discharge must go to the downstream BMP; the outflow cannot be divided to different downstream practices. The downstream practice may include a flow diversion to bypass large storms; however the entire discharge must go to one BMP.

   For example, if multiple rooftop downspouts for a building are consolidated into one spreadsheet entry as practice *2.b. Simple Rooftop Disconnection to C/D Soils*, and the downstream practice for half the building is practice *6.a. Bioretention #1*, and the downstream practice for the other half is practice *8.a. Extended Detention Pond #1*, then the user must use two different drainage area tabs, one for each half of the roof. Additional areas and BMPs can be represented on the same drainage area tab as long as the discharge from each practice is being directed to a single BMP.

   NOTE: *If the user elects to reforest a buffer as a conservation area, or designate an area as a vegetated filter strip, or other land cover conversion that may transition from managed turf to forest/open space as defined in Table 1, then the acreage should be changed accordingly in the Land Cover table on the Site Data tab, as well as on the individual Drainage Area tabs. This will influence the runoff volume and load calculations since the Rv for Forest/Open Space is significantly lower than that of managed turf.*

8. The total impervious cover treated and total turf area treated (acres) in the drainage area is summed at the end of the table of volume reduction BMPs. This serves as a check to ensure that the total area of turf and the total area of impervious cover listed as the Credit Area (column G) does not exceed the total entered in the land cover table (column F).

   NOTE: *The Area Check of the total impervious (cell G71) and total turf (cell G72) area treated in the drainage area is only a check against the totals listed in the land cover table of the drainage area (cells F5 through F7). The Water Quality Compliance tab provides an additional Area Check that ensures the area listed in the Drainage Area Land Cover tables does not exceed the total Land Cover entered into the Site Data tab.*

9. The second table of BMPs includes the practices that remove pollutants but do not remove volume. The same equations are used to calculate the load removed and the load remaining with each practice.

NOTE: *The column for calculating the volume reduction is provided for these practices in order to maintain the columns and allow for easier scrolling up and down the sheet. However, since these practices do not reduce runoff volume, the runoff reduction (column I) does not contain a formula, and will remain zero.*

10. A second area check is provided at the end of the Drainage Area tab that ensures the total area of turf and impervious cover entered as credit area to the volume reduction and pollutant removal BMPs in the drainage area does not exceed the drainage area land cover total.

3.4 Water Quality Compliance

The Water Quality Compliance tab does not require any user input. All the cells are calculations that include:

- A check to ensure that the total area listed in the land cover table of each drainage area does not exceed the area listed on the Site Data tab land cover table.
- A check to ensure that the total acreage of impervious and turf cover listed as Credit Area to be treated the BMPs does not exceed the area listed in the land cover table at the top of the Drainage Area tab.
- The total design runoff treatment volume (cu.ft.) generated on the site by the target rainfall event (cell B11).
- The total phosphorus load reduction (lb/yr) required to meet the site based load limit of 0.41 lb/ac/yr (cell B12).
- The total runoff reduction achieved on the site (cell B14)
- The total phosphorus load reduction achieved (lb/yr) on the site (cell B15).
- The resulting phosphorus load after applying the BMPs (cell B17)
- The remaining phosphorus load reduction (lb/yr) needed to meet the requirement if the selected BMPs have not met the load limit (cell B19).

This last value represents compliance with the stormwater regulations. If the BMP strategy has met the requirements, a congratulatory message appears. If not, this value provides the user with the amount of phosphorus reduction that should be pursued through the implementation of additional on-site BMPs or any available offsite or offset fee compliance options.

Lines 24 through 30 summarize the BMP strategy nitrogen reduction performance. This is for informational purposes as may be needed for TMDL compliance.

3.5 Channel and Flood Protection

The Channel and Flood Protection tab calculates the runoff volume reduction benefit in terms that can be applied to the quantity control requirements of the VSMP Permit regulations. These requirements include provisions that include the post-developed condition volume of runoff:

- o The channel protection requirements include a one-year 24-hour storm peak flow rate reduction based (in part) on the ratio of the post-developed runoff volume to the pre-developed volume.
- o The flood protection requirements include ten-year 24-hour storm peak flow rate reductions as needed to stay within the conveyance capacity of the downstream system.
- o Increased volumes of runoff in the form of sheet flow must be evaluated for impacts to downstream properties.

(The user should carefully review the quantity control requirements found in section 4VAC50-60-66 of the VSMP Permit Regulations.)

The volume reduction achieved by the runoff reduction practices when designed to manage the water quality target rainfall event (one-inch of rainfall) will provide some degree of benefit or credit when complying with any of these quantity control requirements. This credit is applied in the form of a curve number reduction based on the Natural Resource Conservation Service runoff equations provided in Urban Hydrology for Small Watersheds (USDA 1986).

It is important to note that the calculated runoff volume reduction credit is an annual volume reduction credit based on the long term monitored performance of the practice, and not a modeled single event volume reduction. It is also important to note that the spreadsheet calculates the annual reduction credit assuming that the BMP is designed and sized according to minimum requirements of the BMP Design Specifications.

This means that if the user has oversized a practice for whatever reason, the spreadsheet will not reflect additional water quality credit. This also means that the spreadsheet will not reflect additional channel and flood protection credit. However, the designer may choose to analyze the BMP strategy using more rigorous hydraulic analyses, such as individual practice stage-storage-discharge computations and storage indication routing techniques to demonstrate the peak rate reduction. Routing of BMPs can be a difficult and complex task given all the hydrologic and hydraulic variables associated with volume reduction, such as the influence on the time of concentration, the effect of evapo-transpiration and slow release storage within the soil media (extended filtration) etc.

The following provides a brief explanation of the computational procedure provided by the spreadsheet. A more detailed derivation of the curve number adjustment can be found in the VSMH.

1. As a first step, the user should enter the rainfall depth for the Target Rainfall Event, in inches, for the required storms. This will likely be the 1-year, 2-year, and/or 10-year frequency storm events. (Refer to the VSMH for regional rainfall depths).
2. The spreadsheet calculation cells in rows 4 through 22 of column C provides the drainage area (acres) and the runoff reduction volume achieved in each of the

drainage areas. This runoff reduction volume represents the total volume reduction achieved in each drainage area (as provided in cell I77 of each drainage area tab). These values are used to calculate the adjusted curve number for each of the drainage areas as follows (in simple terms):

- The first computation is the determination of the drainage area weighted Curve Number (CN) with no runoff reduction. This is based on the standard land cover CNs for each soil group (**Equation 13**). The weighted CN for the Drainage Area A is provided in cell G35.
- The weighted curve number is used to calculate the value of S (the potential maximum retention after runoff begins) in cell H35. This is a function of the weighted curve number (**Equation 14**).
- The spreadsheet now calculates the runoff volume ($RV_{Developed}$) in watershed-inches with no runoff reduction (line 37, **Equation 15**) and with runoff reduction (line 38, **Equation 16**) for each storm event.
- The spreadsheet determines the adjusted CN for each target rainfall event by referring to a lookup table of Curve Number and corresponding runoff depth (watershed-inches) for each target rainfall depth (row 39). The Adjusted CN can also be determined using Figure 2-2 of TR-55.

3.6 Summary

Special thanks to Michael Baker Engineering’s Henry Manguerra and Sabu Paul for their work in developing the Summary Report Tab.

The user must enable macros for full functionality of the Summary tab. This tab compiles a report style summary of all the BMPs in each drainage area. The site data summary will update Site Data Summary tables as the user enters data into the Site Data tab and the drainage area tabs. However, the user must click on the “Update Summary Sheet” for the individual drainage area summaries to populate.

The user will notice the screen flickering as the macros check each cell in each drainage area tab to identify the BMPs selected, the downstream BMPs (if any), the credit area to each, and the corresponding volume and pollutant load reductions.

The summary will also provide a report of the channel and flood protection adjusted curve numbers for each drainage area.

The user must click on the “print” button and the printer command window will appear

4.0 THE VRRM COMPLIANCE SPREADSHEET DOCUMENTATION

This section provides the equations used in the *calculation cells of the VRRM Compliance Spreadsheet*.

Site Data Tab

Equation 1: Weighted Land Cover Rv:

Equation 1a – Forest:

Rv(F) = [(A(fA) x 0.02) + (A(fB) x 0.03) + (A(fC) x 0.04) + (A(fD) x 0.05)]/SA

Equation 1b – Turf:

Rv(T) = [(A(tA) x 0.15) + (A(tB) x 0.20) + (A(tC) x 0.22) + (A(tD) x 0.25)]/SA

Equation 1c – Impervious:

Rv(I) = 0.95

%Forest = (A(fA) + A(fB) + A(fC) + A(fD))/ A_{site} x 100

%Turf = (A(tA) + A(tB) + A(tC) + A(tD))/A_{site} x 100

%Impervious = (A(iA) + A(iB) + A(iC) + A(iD))/A_{site} 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)

A_{site} = total site area (acres)

Equation 2: Site Rv:

Rv_{site} = Rv(F) x %Forest + Rv(T) x %Turf +Rv(I) x %Impervious

Where:

Rv_{site} = unit less weighted volumetric runoff coefficient for the site
Rv(F) = weighted forest runoff coefficient
Rv(T) = weighted turf runoff coefficient
Rv(I) = weighted impervious cover runoff coefficient

Equation 3: Post Development Treatment Volume:

$Tv_{site} = Rd \times Rv_{site} \times A_{site}/12$

Where:

Tv_{site} = post-development treatment volume for site (acre-ft)
Rd = target rainfall event depth (1" for water quality storm)
Rv_{site} = runoff coefficient for the site
A_{site} = total site area (acres)

Equation 4: Post Development TP Load

$L = P \times P_j \times [Tv_{site}/Rd] \times C \times 2.72$

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_{site} = post-development treatment volume for site (acre-ft) Equation 3
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

Equation 5: Required TP Load Reduction

$Lreduction = L – Ptarget \times A_{site}$

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) = 0.41 lb/ac/yr
A_{site} = total site area (acres)

D.A. Tabs

Equation 6: Runoff Volume from Contributing Drainage Area

This includes the volume of runoff generated by the drainage area and the volume of runoff from the upstream RR practice times the volume reduction credit:

$Cv = Rd \times Rv_{CA} \times CA \times 3{,}630$

Where:

Cv = Runoff volume from contributing drainage area, or Credit Area (cubic feet)
Rd = rainfall depth for target event (1" for water quality storm)
Rv_{CA} = weighted runoff coefficient for credit area (CA) land cover being treated by credit practice
CA = credit area applied to practice (acres, column G)
3,630 = unit adjustment factor, converting acre-inches to cubic feet

Equation 7: Total Runoff Volume to Practice

This includes the runoff volume from the contributing drainage area + the runoff volume from the upstream practice:

Cv_{total} = Cv + Vupstream

Where:

- Cv_{total} = Total runoff volume to practice
- Cv = Runoff volume from credit area (cubic feet, Equation 6)
- Vupstream = Volume from upstream runoff reduction practice (column H)

Equation 8: Runoff Reduction Achieved by Practice (column I)

Cv_{red} = (Rd x Rv_{CA} x CA x 3,630 + Vupstream) x (CR)

Where:

- Cv_{red} = runoff reduction achieved by practice (cubic feet)
- Rd = rainfall depth for target event (1" for water quality storm)
- Rv_{CA} = weighted runoff coefficient for the credit area (CA) land cover being treated by credit practice
- CA = credit area applied to practice (acres, column G)
- 3,630 = unit adjustment factor, converting acre-inches to cubic feet
- Vupstream = Upstream runoff volume directed to credit practice (column H)
- CR = volume reduction performance credit for the practice (column F)

Equation 9: Remaining Runoff Volume Leaving the Practice (column J)

$Cv_{remaining}$ = (Rd x Rv_{CA} x CA x 3,630 + Vupstream) x (1-CR)

Where:

- $Cv_{remaining}$ = runoff reduction achieved by practice (cubic feet)
- Rd = rainfall depth for target event (1" for water quality storm)
- Rv_{CA} = weighted runoff coefficient for the credit area (CA) land cover being treated by credit practice
- CA = credit area applied to practice (acres, column G)
- 3,630 = unit adjustment factor, converting acre-inches to cubic feet
- Vupstream = Upstream runoff volume directed to credit practice (column H)
- CR = volume reduction performance credit for the practice (column F)

OR

$Cv_{remaining}$ = Cv_{total} – Cv_{red}

Where:

- $Cv_{remaining}$ = remaining runoff volume (leaving practice, column J)
- Cv_{total} = total runoff volume to practice (Equation 7)
- Cv_{red} = runoff reduction achieved by practice (Equation 8, column I)

Equation 10: Untreated Pollutant Load to Practice (Phosphorus, column M; Nitrogen, column N)

$L = P \times P_j \times [Tv_{CA}/Rd] \times C \times 2.72 + Lupstream$

Where:

- L = untreated pollutant load to practice (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_{CA} = post-development treatment volume to practice from the credit area (acre-ft) = $[Rd \times Rv_{CA} \times CA] /12$
  Where:
  - Rd = rainfall depth for target event (1” for water quality storm)
  - Rv_{CA} = drainage area weighted Rv for land cover (cell G6 or G7 based on contributing area being turf or impervious)
  - CA = credit area applied to practice (acres)
- 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, 1.86 mg/l for nitrogen
- 2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters
- Lupstream = pollutant load from upstream treatment practice (pounds/yr, Column O)

Equation 11: Total Load Reduction by Practice (Column N)

$L_{red} = L \times [Cv_{total} \times EFF_{TP}/100] / Cv_{total}$

Where:

- L_{red} = total load reduction by practice (lbs/year)
- L = untreated pollutant load to practice (lbs/year, Equation 10, column M)
- Cv_{total} = total runoff volume to practice (Equation 7, or column I + J)
- EFF_{TP} = pollutant removal performance credit (column K)
- 100 = % conversion factor

Equation 12: Remaining Phosphorus Load

$L_{remaining} = L – L_{red}$

Where:

- $L_{remaining}$ = remaining phosphorus load after treatment by the practice (lb/year)
- L = untreated pollutant load to practice (lbs/year, Equation 10, column M)
- L_{red} = load reduction (lbs/year, Equation 11, column N)

Equation 13: Weighted Curve Number (CN)

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)

Equation 14: Potential Maximum Retention After Runoff Begins (S, cell H35)

S = 1000/(CN-10)

Where:

S = potential maximum retention after runoff begins (inches)
CN = weighted curve number

Equation 15: Runoff Volume with no Runoff Reduction (row 37)

$RV_{no\text{-}rr} = (P – 0.2 \times S)^2/(P + 0.8 \times S)$

Where:

$RV_{no\text{-}rr}$ = runoff volume with no runoff reduction (watershed-inches)
P = Rd, rainfall depth for Target Rainfall Event (24-hour storm depth, inches)
S = potential maximum retention after runoff begins (inches), based on CN

Equation 16: Runoff Volume with Runoff Reduction (row 38)

$V_{rr} = [RV_{no\text{-}rr} – (Cv_{redDA} / 3{,}630)] / DA$

Where:

Vrr = Runoff volume with runoff reduction (watershed-inches)
$RV_{no\text{-}rr}$ = runoff volume with no runoff reduction (watershed-inches, Equation 15)
Cv_{redDA} = runoff reduction achieved in the drainage area practice (cubic feet, Equation 8)

3,630 = unit adjustment factor, cubic feet to acre-inches
DA = drainage area (acres)

<u>Equation 17: Adjusted Curve Number (row39)</u>

The adjusted curve number ($CN_{adjusted}$) is determined using a lookup table of curve number and runoff volumes so that:

$CN_{adjusted}$ such that the Runoff Volume, V_{rr}, (watershed-in, Equation 16) =
$(P-0.2 \times S_{adjusted})^2 / (P + 0.8 \times S_{adjusted})$; and $S_{adjusted} = 1000/(CN_{adjusted} -10)$

Where:

$CN_{adjusted}$ = Adjusted curve number that generates a runoff volume (watershed-inches) equal to the drainage area runoff volume with runoff reduction practices (V_{rr}, Equation 16)
V_{rr} = Runoff volume with runoff reduction (watershed-inches)
P = Rd, rainfall depth for Target Rainfall Event (24-hour storm depth, inches)
$S_{adjusted}$ = potential maximum retention after runoff begins (inches) based upon adjusted curve number