DESIGN EXAMPLES: COMPUTING STORMWATER TREATMENT PRACTICE SIZING CRITERIA

Design examples are provided to illustrate how stormwater sizing criteria are computed. Examples are drawn from actual Vermont projects, to the extent possible.

Design Example #1: Residential Development – Mountainside Meadows subdivision

The layout of the Mountainside Meadows subdivision is shown in Figure 1.

Site Data:

Location:	Windsor County, VT
Parcel Area:	87.6 acres
Site Area:	20.0 acres
Drainage Area (DA) #1:	8.0 acres
Impervious Area in DA #1:	1.3 acres
DA #2:	12.0 acres
Impervious Area in DA #2:	1.0 acres
Soils:	100% HSG C

Step 1: Project Layout and Site Design

In this design example, several project layout and site design practices will be applied to meet the Environmental Site Design Standard:

- **Natural Area Conservation**: 47.6 acres of wooded land will be conserved and remain wooded once the project is complete, and thus does not count towards Site Area.
- **Buffer/Floodplain Protection**: Stream buffers within the wooded conservation areas will remain undisturbed
- **Limit Site Clearing/Grading**: The residential lots will not be completely cleared/graded. Roughly half of non-conserved land (20 acres) will ultimately be cleared and remain open or developed after project completion.
- **Post-Construction Soil Depth and Quality**: This standard will be met for any portion of the cleared/graded area that remains pervious (landscaped, lawn, etc.) after the project is complete.

Step 1a: Determine Stormwater Management Goals

Once project layout and site design concepts have been applied and the Site Area is known, the following basic steps should be followed to develop initial targets for stormwater management that will achieve the Water Quality Treatment Standard and the Hydrologic Conditions Standard.

A. Determine Pre-Development Conditions:

The goal for new development projects is to manage stormwater in such a way as to mimic pre-development runoff characteristics – either "meadow in good condition" or "woods in good condition." Because this

project was constructed on a wooded site, the first step will be to calculate the RCN for "woods in good condition" for the project:

HSG	RCN†	Site Area (acres)	% of Site Area
A	38	-	-
B	55	-	-
C	70	20.0	100%
D	77	-	-

† *RCN for "woods in good condition" (Table 2-2c, TR-55, USDA NRCS 1986)*

Since the project site is entirely underlain by HSG C soils, the pre-development RCN_{woods} = 70.

B. Determine Target P_E Using Table 1:

P_E = Rainfall depth used to size non-structural and structural practices

During project planning and preliminary design, site soils and proposed imperviousness are used to determine the target P_E for sizing practices to mimic the predevelopment wooded conditions.

Proposed Imperviousness (%) = Impervious Area (acres)/ Drainage Area (acres)

DA #1 Imperviousness = 1.3 acres / 8.0 acres = 16%

DA #2 Imperviousness = 1.0 acres / 12.0 acres = 8%

From Table 1, checking $\%I_{DA\ \#1}$ = 15% and 20%:

For C soils: 1.2 inches >=P_E>= 1.0 inches will reduce the RCN to reflect "woods in good condition"

From Table 1, checking $\%I_{DA\ \#2}$ = 5% and 10%:

For C soils: P_E>= 1.0 inches will reduce the RCN to reflect "woods in good condition"

Because $\%I_{DA\ \#1}$ = 16%, which is closer to 15%, use P_E= 1.0 inches as the target for non-structural and structural GIS practice implementation for both drainage areas.

In sum, stormwater management target for the Mountainside Meadows subdivision project = P_E = 1.0 inch. Managing this PE using non-structural and structural GSI practices will satisfy both the Water Quality Treatment Standard and the Hydrologic Conditions Standard.

C. Determine Runoff Volume (V_{PE}) Target:

Having determined the P_E target for the project (e.g., the amount of rainfall that needs to be treated to replicate pre-development runoff conditions), the next step is to translate the rainfall amount into a volume target (V_{PE}) for the site. The volume target is calculated as follows:

$$V_{PE\ DA\ \#1} = \frac{(P_E)(R_V)(A)}{12} = \frac{(1.0)(.194)(8)}{12} = 0.129 \text{ ac-ft} * (43{,}560 \text{ ft}^3 / 1 \text{ ac-ft}) = 5{,}619 \text{ ft}^3$$

$$V_{PE\ DA\ \#2} = \frac{(P_E)(R_V)(A)}{12} = \frac{(1.0)(.122)(12)}{12} = 0.122 \text{ ac-ft} * (43{,}560 \text{ ft}^3 / 1 \text{ ac-ft}) = 5{,}314 \text{ ft}^3$$

where:

V_{PE} = Target volume (acre-feet)
P_E = Rainfall depth (inches)
R_V = Runoff coefficient [0.05 + 0.009(I)], unitless
I = Impervious cover (whole number percent)
A = Site area (acres)

The volume target for each drainage area may then be treated by using any one or a combination of structural and non-structural stormwater treatment practices. When two or more structural practices are used, their volumes are easily added; however, when non-structural practices are used it will be necessary to determine an equivalent V_{PE} for these practices. When the cumulative volume for all practices meets or exceeds the target V_{PE} for the project, then the Water Quality Treatment Standard and the Hydrologic Conditions Standard are met. If all options have been examined and the target V_{PE} is not managed completely, limited applicability treatment practices may need to be utilized.

Step 2: Apply Non-Structural Stormwater Management Practices

The non-structural practice of rooftop disconnection was selected to partially meet V_{PE} for the Mountainview Meadows subdivision.

Disconnection of Rooftop Runoff

In the Mountainside Meadows subdivision, all four house rooftops will be disconnected. Two houses are in DA #1 and the other two are in DA #2. The average rooftop area is 2,500 ft^2, so in each DA the net impervious area reduction is:

$$(2 \text{ houses}) \times (2{,}500 \text{ ft}^2) / (43{,}560 \text{ ft}^2/\text{ac}) = 0.11 \text{ acres in each drainage area}$$

The disconnection flow path length for each house will be 35 feet.

When nonstructural practices are used, the P_E will be based on the length of flow over the disconnected area. As shown in Table 2 below, a disconnection flow path length of 35 feet for rooftop runoff is equivalent to treating a P_E of 0.4 inches. The attendant V_{PE} can then be calculated as follows:

$$V_{PE} = \frac{(P_E)(R_v)(A)}{12} = \frac{(0.4)(.95)(0.11)}{12} = 0.003 \text{ ac-ft} * (43{,}560 \text{ ft}^3 / 1 \text{ ac-ft}) = 152 \text{ ft}^3 \text{ for each DA}$$

Table 2: EXAMPLE Factors for Rooftop Disconnection

	Disconnection Flow Path Length (ft.)			
	15	35	55	75
P_E (in.) =	0.2	0.4	0.6	0.8

The remaining volume of runoff that must be captured and treated for each drainage area is:

$$V_{PE\ DA\ \#1} = 5{,}634 \text{ ft}^3 - 152 \text{ ft}^3 = 5{,}482 \text{ ft}^3$$

$$V_{PE\ DA\ \#2} = 5{,}314 \text{ ft}^3 - 152 \text{ ft}^3 = 5{,}162 \text{ ft}^3$$

Step 3: Apply Structural (GSI) Stormwater Treatment Practices

The structural practices of permeable pavement for the driveways, swales, and bioretention will be employed to partially meet V_{PE} for the Mountainview Meadows subdivision.

Permeable Pavements for the Driveways

In the Mountainside Meadows subdivision, all driveways will be constructed with permeable pavement and include 9" of subbase. There is 1,600 ft^2 of driveway in DA #1 and 2,700 ft^2 of driveway in DA #2. Based on the values for permeable pavement on HSG C soils presented in Table 3, below, the treatment volume per square foot is 0.134 feet. Therefore the volume of water captured and treated by the permeable pavement is:

$$V_{PE\ DA\ \#1} = 0.134 \text{ ft} \times 1{,}600 \text{ ft}^2 = 214 \text{ ft}^3$$

$$V_{PE\ DA\ \#2} = 0.134 \text{ ft} \times 2{,}700 \text{ ft}^2 = 362 \text{ ft}^3$$

Table 3: EXAMPLE Factors for Permeable Pavements

Hydrologic Soil Group									
	A			B			C		
subbase	RCN	V_{PE}/ft^2	Equiv P_E (in)	RCN	V_{PE}/ft^2	Equiv P_E (in)	RCN	V_{PE}/ft^2	Equiv P_E (in)
6"	76	0.138	1.7	84	0.101	1.3	93	0.043	0.5
9"	62	0.183	2.3	65	0.175	2.2	77	0.134	1.7
12"	40	0.206	2.6	55	0.196	2.5	70	0.160	2.0

The remaining volume of runoff that must be captured and treated for each drainage area is:

$$V_{PE\ DA\ \#1} = 5{,}482\ ft^3 - 214\ ft^3 = 5{,}268\ ft^3$$

$$V_{PE\ DA\ \#2} = 5{,}162\ ft^3 - 362\ ft^3 = 4{,}800\ ft^3$$

Bioretention

The large cul-de-sac in DA #1 the Mountainside Meadows subdivision will be treated using a bioretention facility. The area draining to the bioretention facility includes the cul-de-sac and a portion of the adjoining roadway - a total 0.85 acres will be captured, including 0.50 acres of impervious surface. The surface area of the proposed bioretention area is 2,500 ft^2. The amount of rainfall captured by this design is estimated as follows:

$$P_E = \frac{15" \times A_f}{DA} = \frac{15" \times 2{,}500\ ft^2}{37{,}026\ ft^2} = 1.01 \text{ inches}$$

The land use within the area draining to the bioretention practice is a combination of imperviousness (21,780 ft^2) and open space (15,246 ft^2) and the percent imperviousness is approximately 59% (R_v = 0.58). The volume of water captured and treated in the bioretention area is:

$$V_{PE} = \frac{(P_E)(R_V)(A)}{12} = \frac{(1.01 \text{ inches})\ (0.58)\ (37{,}026\ ft^2)}{12} = 1{,}807\ ft^3$$

With the implementation of this practice, the remaining volume of runoff that must be captured and treated for DA #1 is:

$$V_{PE\ DA\ \#1} = 5{,}268\ ft^3 - 1{,}807\ ft^3 = 3{,}461\ ft^3$$

Swales

The remaining V_{PE} in DA #1 (3,461 ft^3) and DA #2 (4,800 ft^3) will be treated using grass swales, installed along the roadways within the subdivision. The swales in DA #1 will capture and treat runoff from 0.65 acres of roadway (impervious) surface (or 925 lineal feet); the swales in DA #2 will capture and treat runoff from 0.83 acres of roadway (or 1,250 lineal feet). The swale bottom will be six (6) feet wide and run the full length of the road. In addition to the road runoff, the swale will capture runoff from approximately 0.25 acres of open space – 0.10 acres in DA #1 and 0.15 acres in DA #2. As such, for DA #1:

$$P_{E\ DA\ \#1} = \frac{10" \times A_f}{DA32{,}670\ ft^2} = \frac{10" \times 5{,}550\ ft^2}{} = 1.70 \text{ inches}$$

where DA = the area draining to the practice (acres)
A_f = the surface area of the practice

10" = a constant specific to the practice type, based on the relationship of drainage area to surface area of the practice.

The land use within the area draining to the swale is a combination of imperviousness (28,314 ft^2) and open space (4,356 ft^2) and the percent imperviousness is approximately 87% (Rv = 0.83). The volume of water captured and treated in the bioretention area is:

$$V_{PE} = \frac{(P_E)(R_V)(A)}{12} = \frac{(1.70 \text{ inches})\ (0.83)\ (32{,}670\ ft^2)}{12} = 3{,}839\ ft^3$$

The remaining V_{PE} in DA #1 (3,544 ft^3) will thus be fully treated by the swale.

For DA #2:

$$P_{E\ DA\ \#2} = \frac{10" \times A_f}{DA42{,}689\ ft^2} = \frac{10" \times 7{,}500\ ft^2}{} = 1.76 \text{ inches}$$

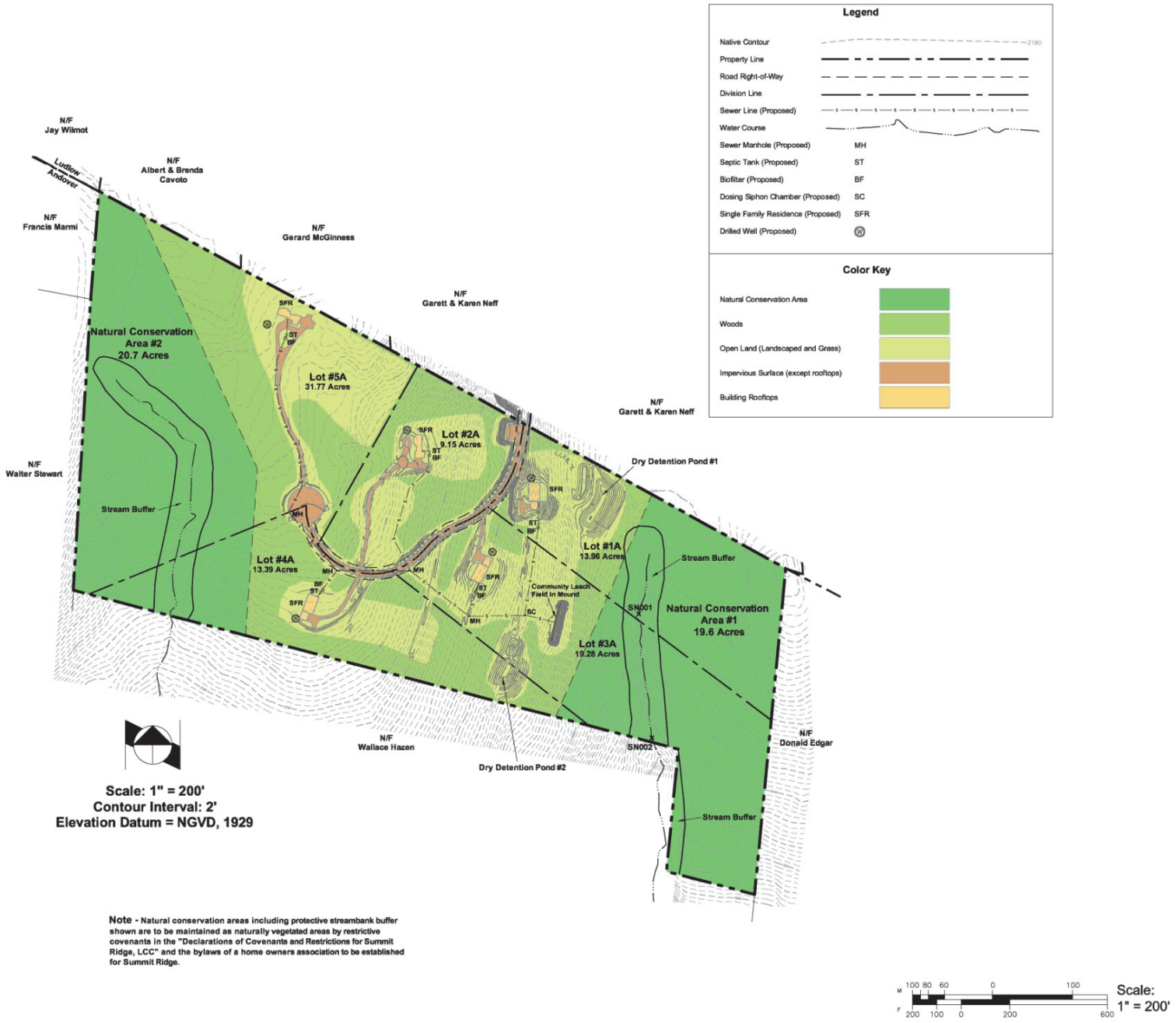
where DA = the area draining to the practice (acres)
A_f = the surface area of the practice
10" = a constant specific to the practice type, based on the relationship of drainage area to surface area of the practice.

The land use within the area draining to the swale is a combination of imperviousness (36,155 ft^2) and open space (6,534 ft^2) and the percent imperviousness is approximately 85% (Rv = 0.82). The volume of water captured and treated in the bioretention area is:

$$V_{PE} = \frac{(P_E)(R_V)(A)}{12} = \frac{(1.76 \text{ inches})\ (0.82)\ (42{,}689\ ft^2)}{12} = 5{,}124\ ft^3$$

The remaining V_{PE} in DA #2 (4,800 ft^3) will thus be fully treated by the swale.

Figure 1: Mountainside Meadows Site Plan



Note - Natural conservation areas including protective streambank buffer shown are to be maintained as naturally vegetated areas by restrictive covenants in the "Declarations of Covenants and Restrictions for Summit Ridge, LCC" and the bylaws of a home owners association to be established for Summit Ridge.

Table 1: RCN Reductions for HSG C Soils

HydroGroup C

Predevelopment CN 70

woods "in good condition"

		Storm Depth Treated by Runoff Reduction Practices (inches)								
%I	CN	1	1.2	1.4	1.6	1.8	2	2.2	2.4	2.6
0%	74									
5%	75									
10%	76									
15%	78									
20%	79	72								
25%	80	72								
30%	81	73	71							
35%	82	73	71							
40%	84	74	71							
45%	85	74	71							
50%	86	75	72							
55%	87	76	72							
60%	88	76	73							
65%	90	77	74							
70%	91	78	75	70						
75%	92	79	76	71						
80%	93	81	77	72						
85%	94	82	78	74						
90%	96	83	79	75						
95%	97	85	81	76	71					
100%	98	86	82	78	73					