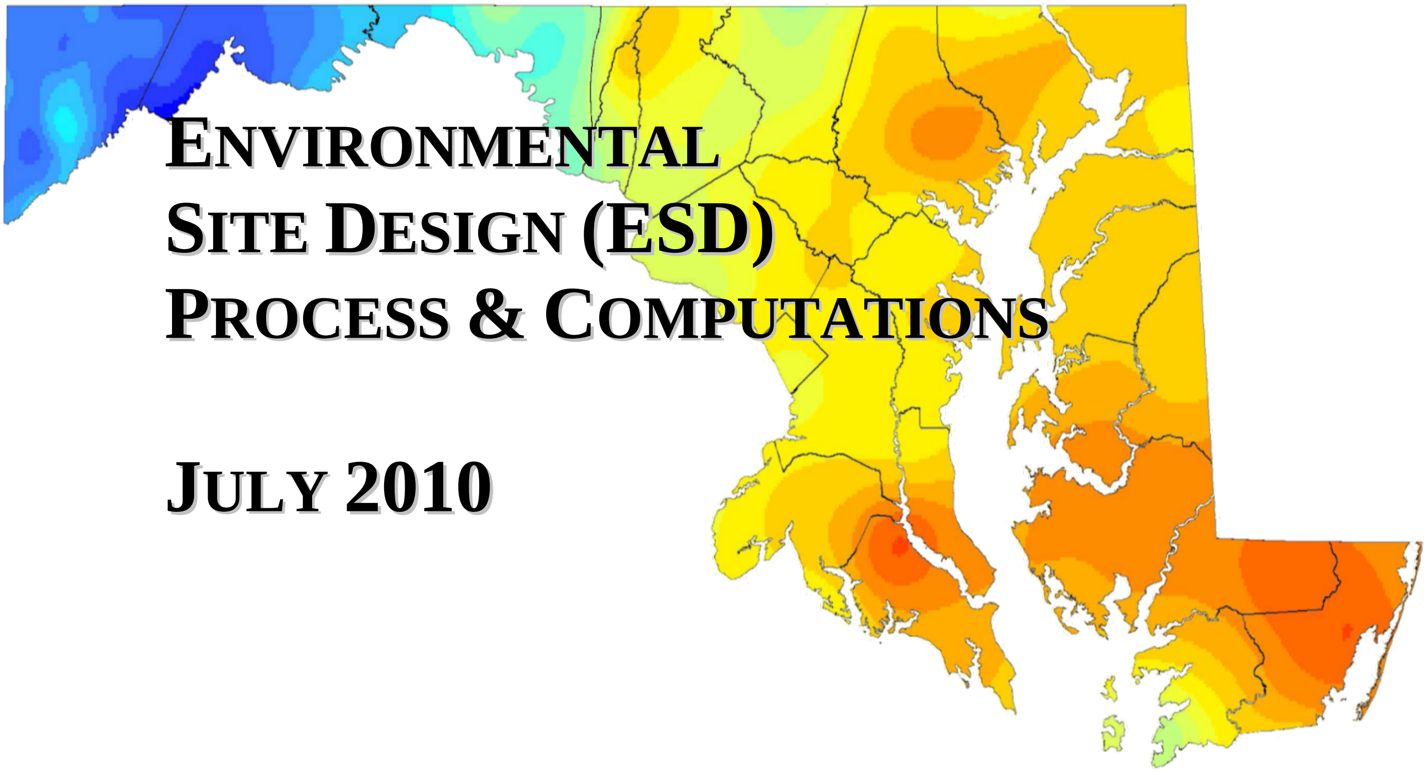
ENVIRONMENTAL SITE DESIGN (ESD) PROCESS & COMPUTATIONS

JULY 2010



MARYLAND

1800 Washington Boulevard, Baltimore, MD 21230-1718 | www.mde.maryland.gov
410-537-3000 | 800-633-6101 | TTY Users 800-735-2258
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Introduction

Current Maryland law and regulations require that ESD be used to the maximum extent practicable (MEP) to control stormwater from new and redevelopment. The Maryland Department of the Environment (MDE) developed and adopted technical requirements for ESD and defined the MEP standard in Chapter 5 of the 2000 Maryland Stormwater Design Manual (Manual). The new criteria for ESD are based on the runoff curve number (RCN) hydrology method developed by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). The basic goal in Chapter 5 is that ESD planning techniques and practices are to be implemented to replicate runoff characteristics similar to "woods in good condition."

MDE developed Table 5.3 (pages 5.21 and 5.22 of the Manual and shown below) to simplify the determination of stormwater management requirements to meet the "woods in good condition" goal. When soil type and proposed site imperviousness is known, Table 5.3 is used to determine the amount of rainfall required to be captured and treated in ESD practices to mimic wooded conditions. This target rainfall amount or "P_E" is used to design ESD practices according to the following equation:

- ESD_v = Runoff volume (in feet^3 or acre-feet) captured in specific ESD practices

  $$= \frac{(P_E)(R_v)(A)}{12} \qquad \text{where:}$$

  - P_E = Rainfall target used to determine ESD goals and the size of practices
  - R_v = the dimensionless volumetric runoff coefficient
    = 0.05 + 0.009(I) and I is percent impervious cover
  - A is the drainage area (in feet^2 or acres)

The MEP standard is met after all reasonable options for implementing ESD are exhausted. When the target P_E is only partially treated in ESD practices, Table 5.3 is used to determine a reduced RCN. This is used to calculate additional stormwater management requirements to meet woods in good condition.

In addition to the new technical design criteria, a comprehensive plans review process is now required. Phased plan submissions must occur at various stages of design in order to ensure compliance with the ESD to the MEP standard. These stages include Concept, Site Development, and Final stormwater management plans. This paper describes the technical procedures and calculations necessary for all phases of a design and gives both the design community and plans review agencies the expected outcomes at each stage.

Table 5.3 Rainfall Targets/Runoff Curve Number Reductions used for ESD

Hydrologic Soil Group A										
%I	**RCN***	**P_E = 1"**	**1.2"**	**1.4"**	**1.6"**	**1.8"**	**2.0"**	**2.2"**	**2.4"**	**2.6"**
0%	40									
5%	43									
10%	46									
15%	48	**38**								
20%	51	40	**38**	**38**						
25%	54	41	40	39						
30%	57	42	41	39	**38**					
35%	60	44	42	40	39					
40%	61	44	42	40	39					
45%	66	48	46	41	40					
50%	69	51	48	42	41	**38**				
55%	72	54	50	42	41	39				
60%	74	57	52	44	42	40	**38**			
65%	77	61	55	47	44	42	40			
70%	80	66	61	55	50	45	40			
75%	84	71	67	62	56	48	40	**38**		
80%	86	73	70	65	60	52	44	40		
85%	89	77	74	70	65	58	49	42	**38**	
90%	92	81	78	74	70	65	58	48	42	**38**
95%	95	85	82	78	75	70	65	57	50	39
100%	98	89	86	83	80	76	72	66	59	40

Hydrologic Soil Group B										
%I	**RCN***	**P_E = 1"**	**1.2"**	**1.4"**	**1.6"**	**1.8"**	**2.0"**	**2.2"**	**2.4"**	**2.6"**
0%	61									
5%	63									
10%	65									
15%	67	**55**								
20%	68	60	**55**	**55**						
25%	70	64	61	58						
30%	72	65	62	59	**55**					
35%	74	66	63	60	56					
40%	75	66	63	60	56					
45%	78	68	66	62	58					
50%	80	70	67	64	60					
55%	81	71	68	65	61	**55**				
60%	83	73	70	67	63	58				
65%	85	75	72	69	65	60	**55**			
70%	87	77	74	71	67	62	57			
75%	89	79	76	73	69	65	59			
80%	91	81	78	75	71	66	61			
85%	92	82	79	76	72	67	62	**55**		
90%	94	84	81	78	74	70	65	59	**55**	
95%	96	87	84	81	77	73	69	63	57	
100%	98	89	86	83	80	76	72	66	59	**55**

Cp_v Addressed (RCN = Woods in Good Condition)

RCN Applied to Cp_v Calculations

Table 5.3 Runoff Curve Number Reductions used for Environmental Site Design (continued)

Hydrologic Soil Group C										
%I	RCN*	P_E = 1"	1.2"	1.4"	1.6"	1.8"	2.0"	2.2"	2.4"	2.6"
0%	74									
5%	75									
10%	76									
15%	78									
20%	79	**70**								
25%	80	72	**70**	**70**						
30%	81	73	72	71						
35%	82	74	73	72	**70**					
40%	84	77	75	73	71					
45%	85	78	76	74	71					
50%	86	78	76	74	71					
55%	86	78	76	74	71	**70**				
60%	88	80	78	76	73	71				
65%	90	82	80	77	75	72				
70%	91	82	80	78	75	72				
75%	92	83	81	79	75	72				
80%	93	84	82	79	76	72				
85%	94	85	82	79	76	72				
90%	95	86	83	80	77	73	**70**			
95%	97	88	85	82	79	75	71			
100%	98	89	86	83	80	76	72	**70**		

Hydrologic Soil Group D										
%I	RCN*	P_E = 1"	1.2"	1.4"	1.6"	1.8"	2.0"	2.2"	2.4"	2.6"
0%	80									
5%	81									
10%	82									
15%	83									
20%	84	**77**								
25%	85	78								
30%	85	78	**77**	**77**						
35%	86	79	78	78						
40%	87	82	81	79	**77**					
45%	88	82	81	79	78					
50%	89	83	82	80	78					
55%	90	84	82	80	78					
60%	91	85	83	81	78					
65%	92	85	83	81	78					
70%	93	86	84	81	78					
75%	94	86	84	81	78					
80%	94	86	84	82	79					
85%	95	86	84	82	79					
90%	96	87	84	82	79	**77**				
95%	97	88	85	82	80	78				
100%	98	89	86	83	80	78	**77**			

Cp_v Addressed (RCN = Woods in Good Condition) (green)

RCN Applied to Cp_v Calculations (yellow)

Technical Considerations for ESD Design

Table 5.3 is based on the "Change in Runoff Curve Number Method" (McCuen, R., MDE 1983) and the RCNs are based on USDA/NRCS hydrology. Primary factors include hydrologic soil group (HSG), land use or cover, hydrologic condition, connectivity of impervious cover, and antecedent runoff condition (ARC). When using the Chapter 5 methodology, the following considerations apply to ESD design:

- Table 5.3 provides ESD management requirements for four distinct HSGs (A, B, C, and D). Predevelopment conditions may show disturbance to existing soils and in these cases the HSG classifications found in USDA/NRCS Soil Surveys and models (e.g., TR55) may not apply. Where site soils have been altered, the following may be used to determine HSG for uncompacted soils:

HSG	USDA Soil Texture
A	**Sand, loamy sand, or sandy loam**
B	**Silt loam or loam**
C	**Sandy clay loam**
D	**Clay loam, silty clay loam, sandy clay, silty clay, or clay**

- Where site soils have been compacted from earlier construction, predevelopment conditions should be based on the most permeable HSGs or from pre-compaction testing.

- The RCN values in Table 5.3 were derived for the average 1-year, 24-hour rainfall event for Maryland, which is 2.7 inches.

- RCNs used for predevelopment characteristics shall be based on "woods in good hydrologic condition" and are labeled in the green area on Table 5.3 for each soil group. A target P_E is determined by correlating the RCN for "woods" with proposed impervious area (%I) and on-site HSGs.

- The target P_E is used to calculate ESD_v which is the volume needed to replicate runoff conditions for woods. Alternative surfaces, nonstructural, or micro-scale practices, may be used to meet ESD goals when designed according to the criteria in the Manual.

- Runoff may be captured and treated using a single ESD practice or technique or a series of interconnected practices and techniques.

- When a project is divided into multiple drainage areas, ESD requirements may be addressed as follows:

  - Where individual drainage areas share a common outfall and the land use or proposed impervious cover is considered relatively homogeneous, ESD requirements could be addressed cumulatively over these areas.

- When a project is divided into separate drainage areas that do not share a common outfall, or when the land use is distinctly non-uniform, ESD requirements should be addressed for each individual drainage area.

- Individual practices may be oversized to compensate or "over manage" for other practices. However, the size of any one practice may not be larger than that required to store runoff for the 1-year 24-hour design storm (Q_1).

Determining Compliance with ESD_v Goals

As noted above, soil type and proposed site imperviousness are used in Table 5.3 to determine the amount of rainfall (or target P_E) required to be treated in ESD practices to replicate runoff conditions on a wooded site. This target P_E may be used in the ESD_v equation (below) to determine the total volume requirements for the site. These targets may be treated by using any one or a combination of practices listed in Chapter 5. The practices include alternative surfaces (green roofs, permeable pavements, and reinforced turf), nonstructural practices (disconnection of rooftop and non-rooftop runoff and sheetflow to conservation areas), and a list of nine different micro-scale practices.

$$ESD_v = \frac{(P_E)(R_v)(A)}{12}$$

ESD_v can be addressed by achieving a cumulative volume provided in ESD practices over the entire site. When two or more micro-scale practices are used, their volumes are easily added. However, when alternative surfaces or nonstructural practices are used, it will be necessary to determine an equivalent ESD volume for these practices. In this way, cumulative volumes for all practices may be determined. Examples of how this may be done are discussed below.

Implementation of alternative surfaces will cause a reduced RCN and these are noted in Chapter 5 in Table 5.4 (green roofs) and Table 5.5 (permeable pavements). Using this information MDE calculated equivalent ESD volumes per square foot (ESD_v/ft^2) for each reduced RCN as noted in Table 1 below. The ESD_v/ft^2 is then multiplied by the surface area of the practice (in ft^2) to determine ESD_v for the alternative surface. This can be subtracted from the target ESD_v for the site and the remaining volume is required to be treated in other practices. An example of how to use Table 1 is provided below.

- When permeable pavements are used on A soils with a 9-inch subbase, a reduced RCN of 62 is assigned (from Table 5.5 of Chapter 5, and Table 1 below).

- MDE has calculated an ESD_v/ft^2 of 0.183 for an RCN of 62 as shown in Table 1. ESD_v is calculated as follows:

$$ESD_v = (ESD_v/ft^2)(A); \text{ where } A = \text{area of the alternative surface in } ft^2$$

- The ESD_v/ft^2 in Table 1 assumes a volumetric runoff coefficient (R_v) of 0.95.

- The ESD_v for this practice can be subtracted from the target ESD_v for the site and the remaining volume is required to be treated in other practices.

- This same procedure can be used for green roofs using the information in Table 1.

Table 1. ESD Values for Green Roofs

Roof Thickness	RCN[1]	ESD_V/ft^2	Equiv. P_E (in.)
2"	94	0.035	0.4
3"	92	0.05	0.6
4"	88	0.077	1
6"	85	0.095	1.2
8"	77	0.134	1.7

ESD Values for Permeable Pavements

	Hydrologic Soil Group								
	A			B			C		
Subbase	RCN[2]	ESD_V/ft^2	Equiv. P_E (in.)	RCN[2]	ESD_V/ft^2	Equiv. P_E (in.)	RCN[2]	ESD_V/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	0.16	2

[1] **Effective RCN from Table 5.4, p. 5.42**

[2] **Effective RCN from Table 5.5, p. 5.48**

When nonstructural practices are used, the P_E or rainfall amount treated, is based on the length of flow over the disconnected area. For example, a disconnection flow path length of 30 feet for rooftop runoff is equivalent to treating a P_E of 0.4 inches of rainfall. The P_E of 0.4 inches may be used in the ESD_v equation to determine the volume provided for this practice. As in the example described above, the area (A) and volumetric runoff coefficient (R_v) parameters shall be specific to the impervious area that is disconnected. The calculated volume may be added to the volume of other ESD practices to provide a total ESD_v achieved for the site.

After alternative surfaces and nonstructural practices are implemented, the remaining rainfall/volume requirements may be treated in micro-scale practices. Guidelines for calculating the volume available for specific micro-scale practices are outlined in Chapter 5. In general, this involves accounting for the storage above the practice and within the filter media. The volume provided in each micro-scale practice is added to all other practices to determine a total volume for the entire ESD system.

When the cumulative volume for all practices meets or exceeds the target ESD_v for the project, then MEP goals are met. However, when these goals are not met, the system must be re-evaluated until the review agency is satisfied that all reasonable ESD options have been exhausted. If all options have been examined and the rainfall/volume targets are not managed completely, structural practices will be necessary.

When structural practices are necessary, it will be useful to calculate the cumulative rainfall amount that is treated in the ESD system. When the rainfall amount is known, Table 5.3 is used to determine a reduced RCN. The P_E treated for the system may be determined by rearranging the ESD_v equation as follows:

$$P_E = \frac{12 \times ESD_v}{R_v \times A}$$

This equation will convert the volume available in all ESD practices to a treated rainfall amount (P_E). The area (A) and volumetric runoff coefficient (R_v) parameters used in the equation shall be specific to the entire system of ESD practices. Table 5.3 is then used to correlate the P_E for the system with percent impervious area to obtain a reduced RCN. Using the reduced RCN, the volume of runoff from the proposed project is determined and the volume required in structural practices to replicate runoff to woods in good condition is calculated.

Design Equations for Estimating P_E

The design criteria for micro-scale practices in Chapter 5 provide equations that estimate P_E when certain filtration and infiltration practices are used. These equations (5.1, 5.2, and 5.3) allow for quick estimates of the rainfall amount that may be treated in an individual facility. In addition, the equations may be rearranged to solve for A_f to estimate the surface area needed to achieve ESD goals. These equations are best used as planning and design tools during the concept review process. The specific practices that apply these equations are landscape infiltration, micro-bioretention, bio-swales, grass swales, and rain gardens. As an example, equation 5.1 (Manual, page 5.85) is shown below for landscape infiltration:

$$P_E = 20 \times \frac{A_f}{DA}$$

where: P_E = specific rainfall captured and treated by the practice
A_f = surface area of the practice
DA = contributing drainage area to the practice
20 = a surface area constant (explained below)

Equations 5.1, 5.2, and 5.3 were derived from equations in Appendix D.13 and Chapter 3 of the Manual, which are used to determine the minimum surface area of filtering and infiltration practices. An analysis of the original equations in the Manual found that when practices are designed to treat impervious areas close to the source (e.g., the drainage area is at or near 100% impervious), the amount of rainfall treated can be based on the relationship between drainage area and surface area of the facility. The drainage area to surface area relationships are approximately 5% for landscape infiltration; 7.5% for micro-bioretention and bio-swales; and 10% for rain gardens.

MDE used these relationships to develop the surface area constant provided in equations 5.1, 5.2, and 5.3. For example, in equation 5.1, the surface area constant is 20. This was determined by using the drainage area to surface area ratio of 5%, and the surface area to drainage area ratio is equal to the reciprocal, or 20. The surface area constants in equations 5.2 (Manual, page 5.98) and 5.3 (Manual, page 5.105) were determined in a similar fashion.

During the early stages of project planning, these equations can be used to estimate the amount of management that could be achieved on site. When considering the areas available for ESD implementation, a quick estimate of the amount of rainfall (P_E) that could be treated is provided. This allows an early assessment of the design during concept reviews when comparing to P_E targets.

Another application of the equations above is to estimate the surface area (A_f) needed for an individual facility to meet ESD goals. For example, by rearranging equation 5.1 the surface area (A_f) of a landscape infiltration practice required to meet a specific P_E can be calculated as follows:

$$A_f = DA \times \frac{P_E}{20}$$

These surface area estimates are conservative and therefore, can be considered a first step toward evaluating compliance with ESD targets. The designer can demonstrate the feasibility of compliance with management requirements on a two dimensional level during concept plan submissions. When A_f is provided, it can reasonably be assumed that the corresponding ESD volumes will be met as long as the minimum depths specified for each practice are used.

As a project moves toward the site development phase, the initial estimates for surface area and P_E treated could be adjusted as the dimensions of individual practices are fine tuned. For example, it may be desirable to make an individual practice deeper to provide greater volume (and greater P_E treated) and compensate for other drainage areas that do not have enough management. In addition, site constraints may dictate that the surface area of a facility may not be as large as originally planned, and therefore, the depth would need to be adjusted in order to achieve the required volume.

Design Process and ESD Computations – A Step by Step Overview

The comprehensive plans review process detailed in Chapter 5 requires that plans be submitted for review and approval during the Concept, Site Development, and Final Design stages. This is an iterative process that builds upon each stage of design to provide a stormwater strategy that considers the unique characteristics of the site. This will ensure that all reasonable options for implementing ESD are exhausted in the early stages of design in order to comply with the MEP standard.

The flow chart on page 12 shows how the information in each step of the review process works toward the final design. During the Concept phase, options for implementing alternative surfaces, nonstructural practices, and micro-scale practices are evaluated. Calculations will assess the feasibility of achieving P_E and ESD_v goals. The Site Development phase provides more detailed computations for individual drainage areas as grading plans are finalized. The dimensions of individual practices are adjusted in order to optimize all ESD opportunities and to account for site constraints. The ESD to the MEP standard must be demonstrated prior to proceeding to the next phase. Final plans will include details of ESD designs and computations for any structural practices necessary to address total treatment requirements (e.g., Cp_v, Qp, or Q_f).

The design process for ESD implementation is presented below. This will describe the information presented on stormwater management plans to demonstrate compliance at the Concept, Site Development, and Final Design phases. With each phase, specific requirements are outlined, the expected outcome for both designers and plans reviewer is stated, and the specific technical process is presented. It should be noted, that the process described below is a suggested methodology. Because ESD practices and techniques involve a wide array of choices and decisions that may be made on any given project, there may be other acceptable means for achieving ESD to the MEP.

Concept Plan Design and Computations

> The Concept design phase is the first step in project development and includes mapping natural resources, an initial layout of the project, and preliminary locations of ESD practices and management options. The purpose is to ensure that all options for ESD are exhausted prior to progressing toward more detailed phases of project design. The developer/designer must demonstrate how ESD is to be implemented and review authorities will evaluate the design to determine the feasibility of meeting the MEP standard.

1. **Determine Stormwater Management Requirements** – This initial step will evaluate proposed conditions and estimate stormwater treatment requirements to replicate runoff characteristics from a wooded site. Implementation of ESD to meet management requirements will include the following information:

   - **Initial Site Data** – Natural resources and existing conditions are mapped and proposed limits of disturbance, site layout of buildings, roadways and impervious areas are identified. Site data will include drainage areas, soil types, land use, and proposed impervious cover.

   - **Determine RCNs for Wooded Conditions** – Table 5.3 tabulates the RCNs for wooded conditions for A, B, C, and D soils. A composite RCN can be computed for "woods in good condition" when different soil types exist on site.

   - **Determine ESD Targets** – Existing soils and impervious cover estimates are used to determine rainfall targets (P_E's) from Table 5.3. The total ESD_v required is then calculated for the target rainfall (P_E).

2 **Preliminary ESD Options** – ESD strategies are employed such as reducing impervious area, protecting natural resources, maximizing the use of landscaped areas for disconnecting runoff, allowing sheetflow, and integrating practices into the proposed site layout of buildings and infrastructure. The feasibility of using alternative surfaces, nonstructural, and micro-scale practices is evaluated and the location of potential management areas is

identified. A drawing or sketch identifying the preliminary location and approximate size of each practice is provided.

3 **Preliminary Design**– Using the location and areas available for ESD, an estimate of the amount of rainfall (P_E) captured and treated in these practices will be provided. Initial calculations will also be made to estimate proposed dimensions to show the total volume provided in ESD practices. The preliminary design will show how the proposed rainfall targets and corresponding ESD_v can be achieved by using a combination of alternative surfaces, nonstructural, and micro-scale practices.

➥ ***Concept plans may be submitted after completing these steps. Documentation will be provided to demonstrate that all opportunities for using ESD practices have been evaluated. The plan review authorities will determine whether the proposal is feasible and compliance with the MEP standard is addressed.***

Site Development Plan Design and Computations

The Site Development plan will provide more details and computations as a project progresses toward Final design. Comments from the review agency during Concept approval will be addressed and the location of practices, their drainage areas, and the management options to be implemented will be provided at this stage. This step provides an interim check by review agencies to assess compliance with the ESD to the MEP standard before allowing the design to progress to the final phase.

4 **ESD Practice Design** – After the Concept phase, the final site layout, exact impervious area locations and acreages, proposed topography, and proposed drainage areas will be provided. As site utilities such as water, sewer, electric, and storm drains are located, the design of ESD practices becomes progressively more detailed. Options to use alternative surfaces and nonstructural practices should be maximized to provide treatment for the target rainfall (P_E). Micro-scale practices are sited and final dimensions are provided so that calculations can show the volume of runoff captured and treated. More detailed calculations will quantify the cumulative effects of practices used in combination or as a treatment train.

5 **Design Assessment** - After completing the design of ESD practices, the next step is to determine if "woods in good condition" goals have been met. This requires evaluating the cumulative effect of all practices on site. This is accomplished as follows:

- **Determine if ESD Targets are Met:** After alternative surfaces and nonstructural practices have been implemented, the remaining volume to be treated in micro-scale practices is determined. When the total ESD_v is provided in all practices, then ESD to the MEP is achieved and plans may proceed toward final design.

- **Evaluate Additional ESD Opportunities:** If the required ESD_v is not achieved, then the project will be re-evaluated to determine whether additional ESD measures can be reasonably implemented. The final dimensions of ESD practices may be adjusted to provide greater volume. When the review agency agrees that ESD to the MEP has been achieved, structural practices may be used to address any remaining management requirements.

- **Determine Additional Management Requirements:** When structural practices are determined to be necessary, the amount of rainfall treated (P_E) with the proposed ESD practices is determined. Table 5.3 is used to correlate the P_E treated with the reduced RCNs. Remaining stormwater management requirements are calculated to mimic runoff conditions for a wooded site.

- **Design Structural Practices if Necessary:** Structural practices are located and designed according to criteria in Chapter 3 of the Manual.

- **Complete Design:** Before submitting Site Development plans, the designs for the ESD practices should be ready for completion. This includes all pertinent details, standards, and specifications needed to verify that designs are in accordance with the requirements listed in Chapter 5.

➥ ***Site Development plans may be submitted after completing these steps. Documentation will be provided to demonstrate that ESD practices have been implemented to the MEP with the proposed plan. Review agencies will need to confirm that ESD has been implemented to the MEP prior to allowing structural practices to address remaining management requirements.***

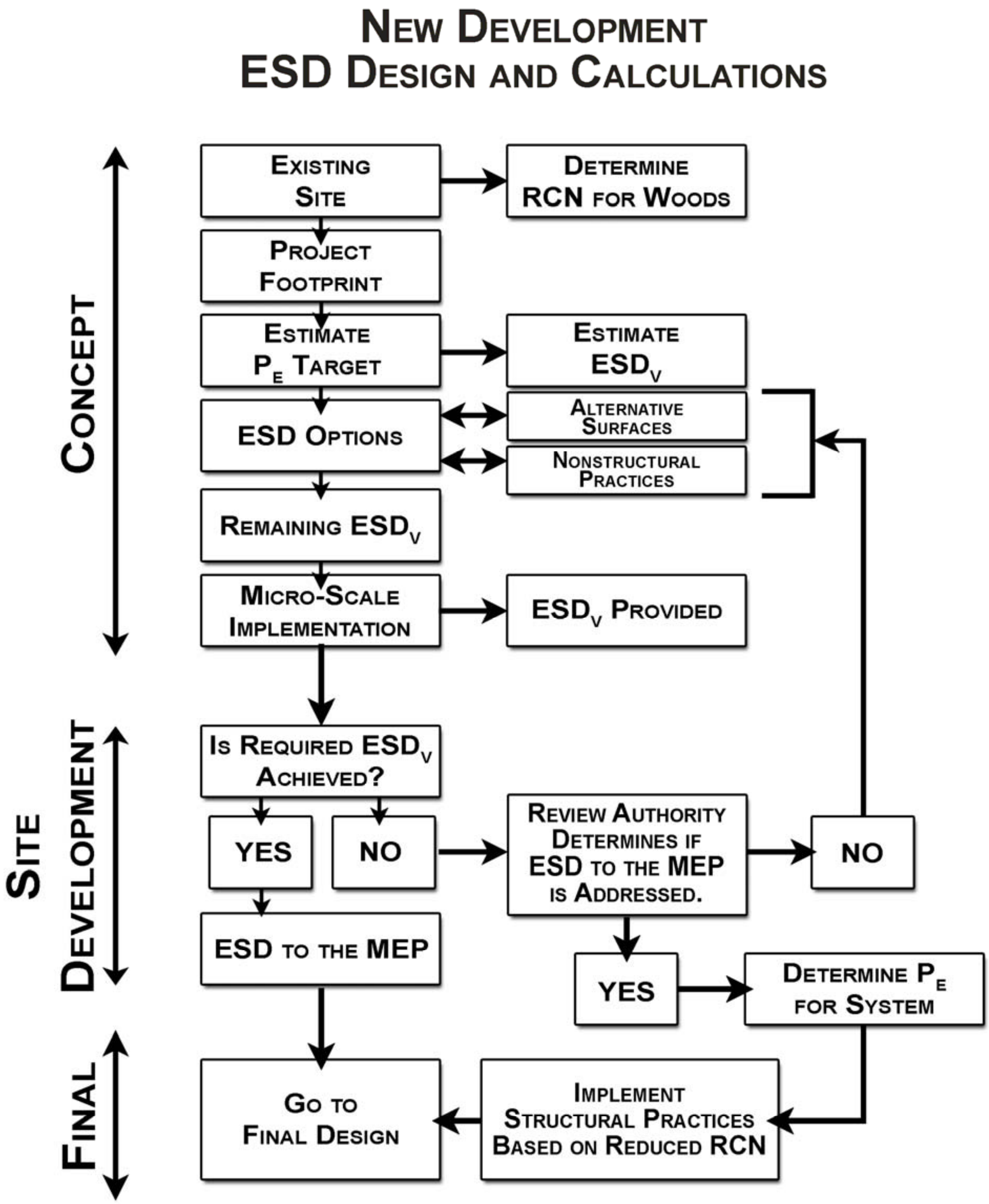
Final Plan Design and Computations

After Site Development plan approval, the developer may prepare Final plans by addressing comments from the review agency. After all reasonable ESD options have been exhausted, structural practices may be needed to address any remaining stormwater requirements. Final construction drawings, hydrology and hydraulic computations, and final erosion and sediment control plans will be submitted at this phase of design.

6 **Finalize ESD Design and Address Remaining Stormwater Requirements** – Any comments from the review agencies will be addressed as details and computations for ESD practices are completed. After all reasonable options for implementing ESD have been exhausted, the design of structural practices may be needed to address any remaining Cp_v or local Q_p and Q_f requirements.

➥ ***Final plans may be submitted after completing these steps***

Design Examples are provided below. A flow chart is also provided to outline the ESD design and calculation procedures used in the examples. This information is intended to provide guidance on how to design and assess compliance with ESD requirements. However, because a range of options for ESD implementation exists on every development site, and the size and complexity of a project may dictate more detailed information at different stages of review, the following method is not the only way to show compliance with the MEP standard.


New Development
ESD Design and Calculations
Concept
Site Development
Final
Existing Site
Determine RCN for Woods
Project Footprint
Estimate P_E Target
Estimate ESD_V
ESD Options
Alternative Surfaces
Nonstructural Practices
Remaining ESD_V
Micro-Scale Implementation
ESD_V Provided
Is Required ESD_V Achieved?
YES
NO
Review Authority Determines if ESD to the MEP is Addressed.
NO
ESD to the MEP
YES
Determine P_E for System
Go to Final Design
Implement Structural Practices Based on Reduced RCN

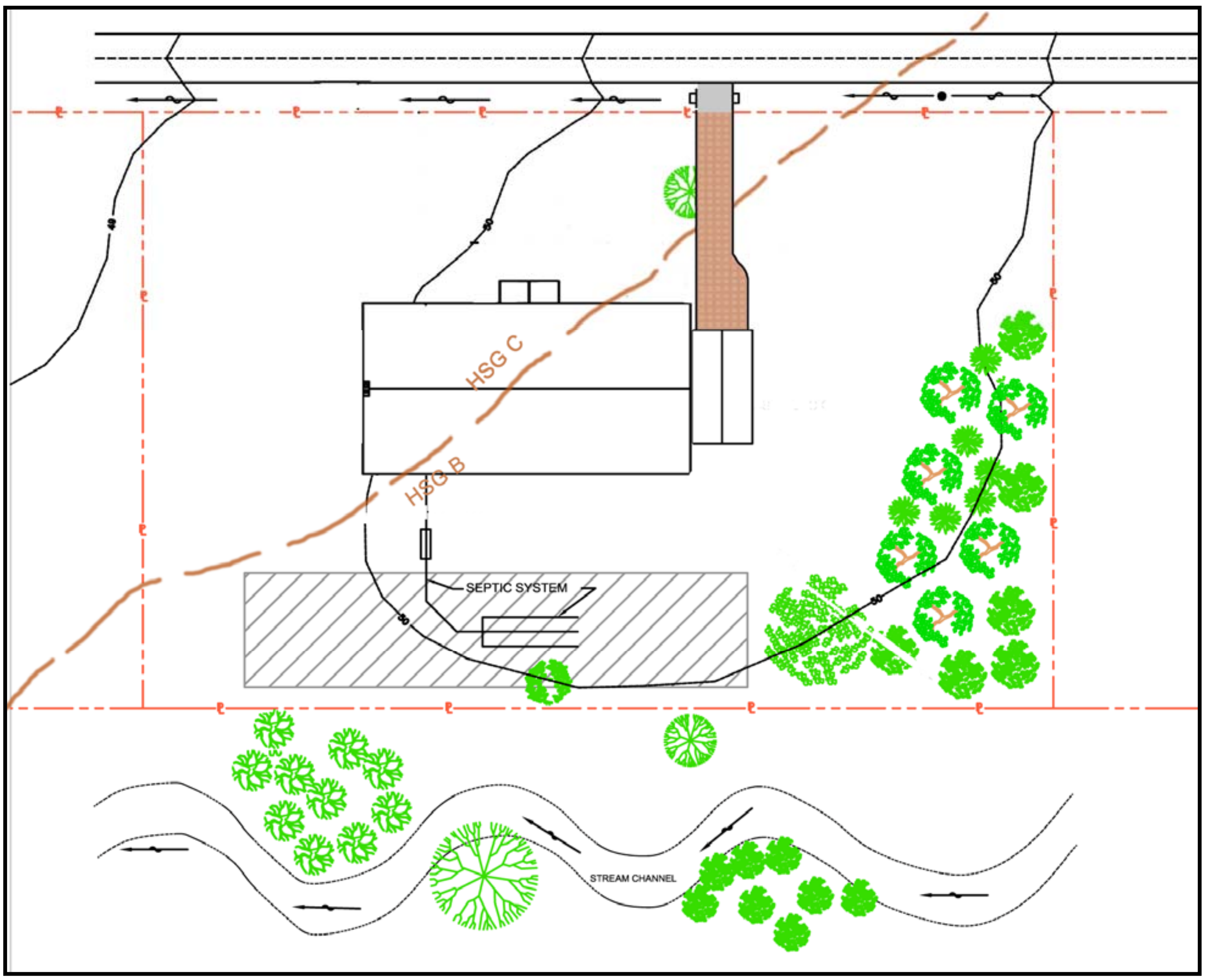
Example No. 1 – Single Family Residential Construction

The proposed project involves the construction of a house, garage, and driveway on an existing residential lot. Sketches of the existing lot and proposed work are shown in Figure 1.

Concept Plan Design and Computations

The Concept Plan represents the first steps in a project's development and includes mapping of natural resources, initial project layout, and the preliminary design of ESD practices and techniques. During this phase, the designer demonstrates how ESD will be implemented to meet the MEP standard. The purpose is to show the review authorities that all opportunities for implementing ESD have been exhausted before proceeding with more detailed design.

Figure 1. Single Family Lot – Proposed Layout



Step 1 – Determine Stormwater Management Requirements

Initial Site Assessment (Site Data):

Existing Conditions

Total Drainage Area:	40,000 ft^2
Soil Types:	60% (24,000 $feet^2$) HSG B
	40% (16,000 $feet^2$) HSG C
Land Use:	Residential
Lot Size:	40,000 ft^2

Proposed Layout

	HSG B/HSG C
Total Impervious Cover:	7,900 ft^2 (4,150 ft^2/3,750 ft^2)
House:	6,900 ft^2 (4,150 ft^2/2,750 ft^2)
Driveway:	1,000 ft^2 (0.00 ft^2/1,000 ft^2)

Determine RCN's for Wooded Conditions:

Because there are different soil types on site, a composite RCN for "woods in good condition" must be calculated. According to TR55 and as found in Table 5.3, the RCN's for "woods in good condition" in HSG B and C are 55 and 70 respectively. Using these values, the composite RCN is:

$$\mathbf{RCN_{woods}} = \frac{(55 \times 24{,}000\,ft^2) + (70 \times 16{,}000\,ft^2)}{40{,}000\,ft^2} = 61$$

Determine ESD Targets:

Rainfall targets (see Table 5.3) for meeting ESD goals may be computed using the existing soils and impervious cover estimates from the initial site assessment. For this example, the proposed impervious area is 7,900 ft^2 and the total lot area is 40,000 ft^2 (see above).

Compute Percent Imperviousness

$$\begin{aligned} I &= \text{Impervious Area} / \text{Total Area} \\ &= 7{,}900\ ft^2 / 40{,}000\ ft^2 \\ &= 19.75\% \end{aligned}$$

<u>Use 20%</u>

Using I = 20%, the dimensionless volumetric runoff coefficient, R_v may be calculated:

$$R_v = 0.05 + 0.009(I)$$
$$= 0.05 + 0.009(20)$$
$$= 0.23$$

By using Table 5.3 for HSG B and I = 20% as shown:

		Hydrologic Soil Group B				
%I	RCN*	P_E = 1"	1.2"	1.4"	1.6"	1.8"
0%	61					
5%	63					
10%	65					
15%	67	55				
20%	68	60	55	55		
25%	70	64	61	58		
30%	72	65	62	59	55	
35%	74	66	63	60	56	

A target $P_E \geq 1.2$" will reduce the RCN to "woods in good condition."

And by using Table 5.3 for HSG C and I = 20%:

		Hydrologic Soil Group C				
%I	RCN*	P_E = 1"	1.2"	1.4"	1.6"	1.8"
0%	74					
5%	75					
10%	76					
15%	78					
20%	79	70				
25%	80	72	70	70		
30%	81	73	72	71		

A target $P_E \geq 1.0$" will reduce RCN to "woods in good condition."

There are different soil types on site and a composite P_E may be calculated. Using the values from Table 5.3, the composite P_E is:

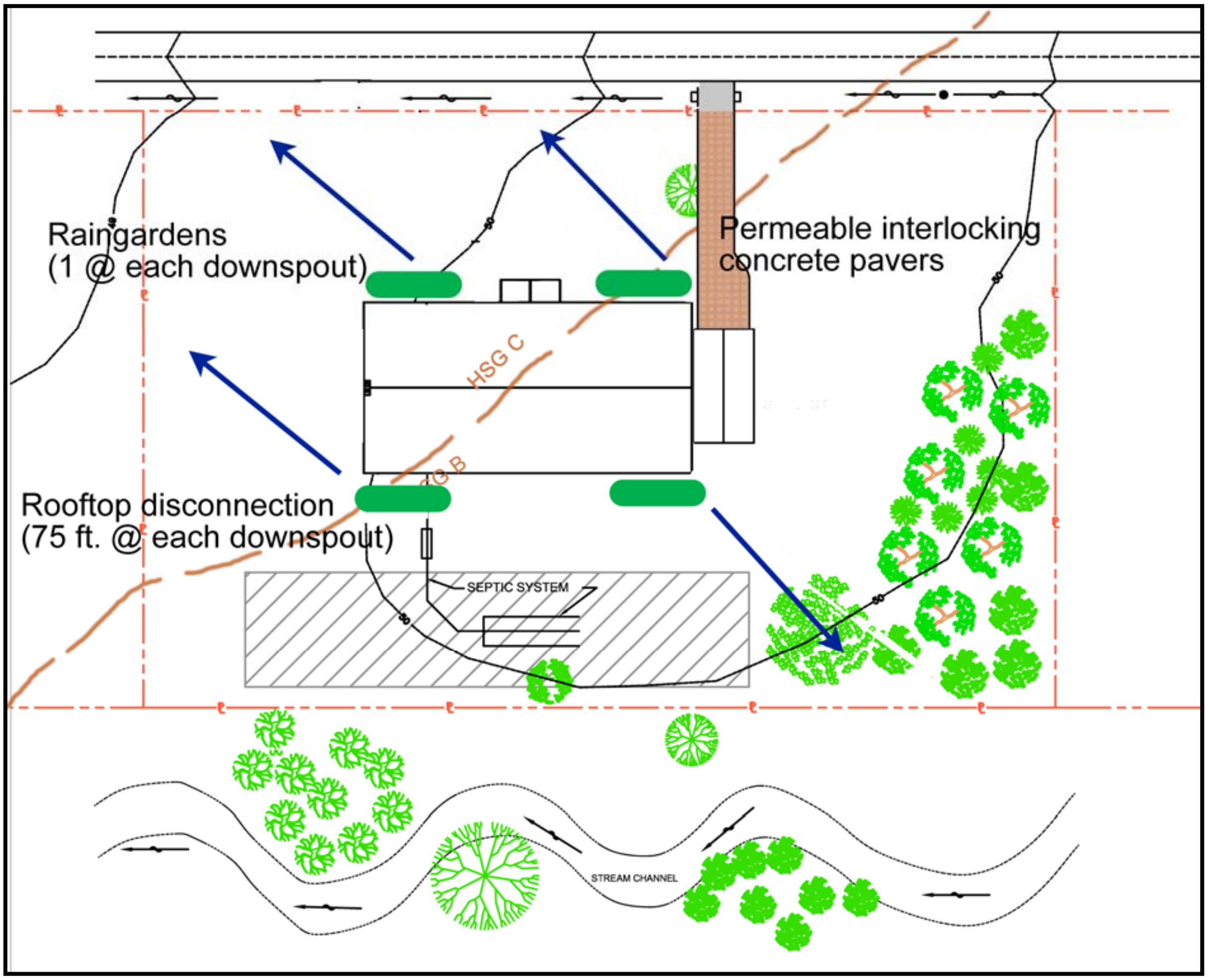
$$P_E = \frac{(1.2 \text{ inches} \times 24{,}000 \text{ ft}^2) + (1.0 \text{ inches} \times 16{,}000 \text{ ft}^2)}{40{,}000 \text{ ft}^2} = 1.1 \text{ inches}$$

The target P_E = 1.1 inches. An estimated ESD_v for the project is then calculated using this value:

$$ESD_V = \frac{(P_E)(R_V)(A)}{12} = \frac{(1.1 \text{ inches})(0.23)(40{,}000 \text{ ft}^2)}{12} = 843.3 \text{ ft}^3$$

Use 845 ft^3

Figure 2. Concept Design Layout of ESD Practices and Techniques



Step 2 – Preliminary ESD Options

ESD requirements must be addressed for the entire limit of disturbance. This corresponds to an ESD_v of 845 ft^3 of runoff that must be captured and treated. To accomplish this, a combination of alternative surfaces, nonstructural techniques, and/or micro-scale practices will be used to treat the runoff from 1.1 inches of rainfall over the entire site. With respect to alternative surfaces, the proposed house will have a steep roof (> 30%) and using a green roof is not an option. However, permeable pavement will be used to surface the driveway.

Nonstructural techniques like the disconnection of rooftop and non rooftop runoff work well in residential settings. However, these practices only capture and treat up to 1 inch of rainfall. Therefore, micro-scale practices must be used in combination with the nonstructural techniques to fully address ESD requirements. Practices that work well in residential settings are raingardens, rain barrels, dry wells, infiltration berms, and bio-swales. For this specific design, treatment will be provided using a combination of permeable pavement, disconnection of rooftop runoff, and raingardens. The preliminary location and size of each practice is shown in Figure 2.

Step 3 – Preliminary Design

Concept Design – Use Permeable Pavements (A-2) for the Driveway:

A standard, paved driveway has an RCN of 98 (100% impervious). For HSG C, the reduced RCN's for permeable pavements range from 70 to 93 depending on the depth of the subbase (vide Table 5.5, p. 5.48). Pavements with a either a 9" subbase or a 12" thick subbase (P_E = 1.7" and 2", respectively, see Table 1, p.6 "ESD Values for Permeable Pavements") meet or exceed the design target P_E of 1.1". Because it requires less structure (e.g., underdrains) and provides more treatment, permeable pavement with a 12" subbase will be used for the driveway.

According to Table 1, the treatment volume per square foot (ESD_v/ft^2) for permeable pavements with a 12" subbase in HSG C is 0.16 feet. The size of the proposed driveway is 1,000 ft^2. Therefore, the volume of water captured and treated by the permeable pavement is:

$$\mathbf{0.16\ ft \times 1{,}000\ ft^2 = 160\ ft^3}$$

Given that the target ESD_v for the design is 845 ft^3 and that the permeable pavement treats 160 ft^3 of runoff, the remaining volume of runoff that must be captured and treated is:

$$\mathbf{845\ ft^3 - 160\ ft^3 = 685\ ft^3}$$

Concept Design – Use Rooftop Disconnection (N-1):

The length of the flow path from the front of the house to the property line exceeds 75 feet. Therefore, the amount of rainfall captured and treated using rooftop disconnection is 1.0 inch (see Manual, Table 5.6, p.5.59). Given that the house is 6,900 ft^2 and 100% impervious (R_V = 0.95), the volume of water treated by the rooftop disconnection is:

$$\mathbf{V = \frac{(P)(R_V)(A)}{12} = \frac{(1.0\ inch)(0.95)(6{,}900\ ft^2)}{12} = 546\ ft^3}$$

After factoring in the permeable pavement, the volume of water that must be captured and treated is 685 ft^3. Using disconnection of rooftop runoff treats 546 ft^3 of runoff, and the remaining volume of runoff that must be captured and treated is:

$$\mathbf{685\ ft^3 - 546\ ft^3 = 139\ ft^3}$$

Concept Design – Use Raingardens (M-7):

A raingarden will be located at each corner of the house (DA to each = 1,725 ft^2) to capture the additional 139 ft^3 needed to meet the target ESD_v. Given that the rooftop is 100% impervious (R_v = 0.95), and that each raingarden will capture approximately 35 ft^3 (139 ft^3/4 = 34.75 ft^3), the amount of rainfall that must be captured in each raingarden may be calculated as:

$$P_E = \frac{12 \times ESD_V}{R_V \times A} = \frac{12 \times 35\ ft^3}{0.95 \times 1{,}725\ ft^2} = 0.26\ inches$$

By rearranging Equation 5.3 (Manual, page 5.105), the surface area (A_f) of each raingarden may be estimated as follows:

$$A_f = DA \times \frac{P_E}{10} = 1{,}725\ ft^2 \times \frac{0.26\ inch}{10} = 44.8\ ft^2$$

Concept Design Assessment:

The requirements for the proposed design were to capture the runoff from at least 1.1 inches of rainfall across the site. This equated to an ESD_v of 845 ft^3 of runoff. The total volume captured by the combination of permeable pavement (160 ft^3), rooftop disconnection (546 ft^3), and raingardens (139 ft^3) equals 845 ft^3. Because this volume of runoff equals the required ESD_v, the Concept plan complies with the MEP standard. Concept plans including all documentation needed to demonstrate that the proposal is feasible, may be submitted after completing these steps.

Site Development Plan Design and Computations

As discussed above, the Site Development plan provides more details and computations as the design progresses toward the final stages. Any comments from the review agency on the Concept plan should be addressed and the details (e.g., drainage area, size) and location of ESD practices and techniques are provided at this stage. In this example, the final designs of each raingarden should be completed. Also, one item of concern that must be addressed for this example is that the raingardens in the back of the house are too close to the septic system.

Step 4 – ESD Practice Design

In the Concept plan, ESD requirements were addressed by capturing and treating the ESD_v (845 ft^3) in a combination of permeable pavement, disconnection of rooftop runoff, and a raingarden at each corner of the house. Because of the proximity of the septic system, the two raingardens located at the back of the house must be removed from the plan and alternate treatment provided. In the original concept each of these raingardens was designed to capture 35 ft^3 of runoff from the rooftop.

Because the use of alternative surfaces and nonstructural techniques has been maximized, micro-scale practices must be used to capture and treat the additional runoff. In this case, the size of the raingardens located in the front of house will be increased to capture some of this runoff. Any remaining volume will be captured in rain barrels located at the downspouts in the rear of the house.

Site Development Design –Use Raingardens (M-7) for the Front of the House:

According to the Concept plan, each raingarden was designed originally to capture 35 ft^3 of runoff for a combined volume of 140 ft^3. To accomplish that, each was designed with a surface area of about 45 ft^2. However, the elimination of two of the raingardens from the plan means that the remaining ones must be made larger to capture additional runoff. Therefore, the surface area of each raingarden will be increased from 45 ft^2 to 65 ft^2. Each raingarden will be 6.5 ft. by 10 ft. with a 0.5 ft. (6-inch) ponding depth. Each raingarden also will have 1 ft. layer of planting soil and a 0.25 ft. (3-inch) mulch layer with a porosity (*n*) of 0.4. The total storage volume in each raingarden is equal to:

$$\underbrace{(6.5\,\text{ft} \times 10\,\text{ft} \times 0.5\,\text{ft})}_{\text{ponding depth}} + \underbrace{[(6.5\,\text{ft} \times 10\,\text{ft} \times 1.25\,\text{ft}) \times 0.4]}_{\text{storage in media}} = 32.5\,\text{ft}^3 + 32.5\,\text{ft}^3 = 65\,\text{ft}^3$$

The total storage capacity in each raingarden is 65 ft^3 and the combined treatment volume of the system is 130 ft^3. This is less than the 140 ft^3 that the system needed to store to meet ESD goals. Therefore, rain barrels will be needed at the back of the house to capture and treat the remaining volume of 10 ft^3.

Site Development Design –Use Rain Barrels (M-1) for the Back of the House:

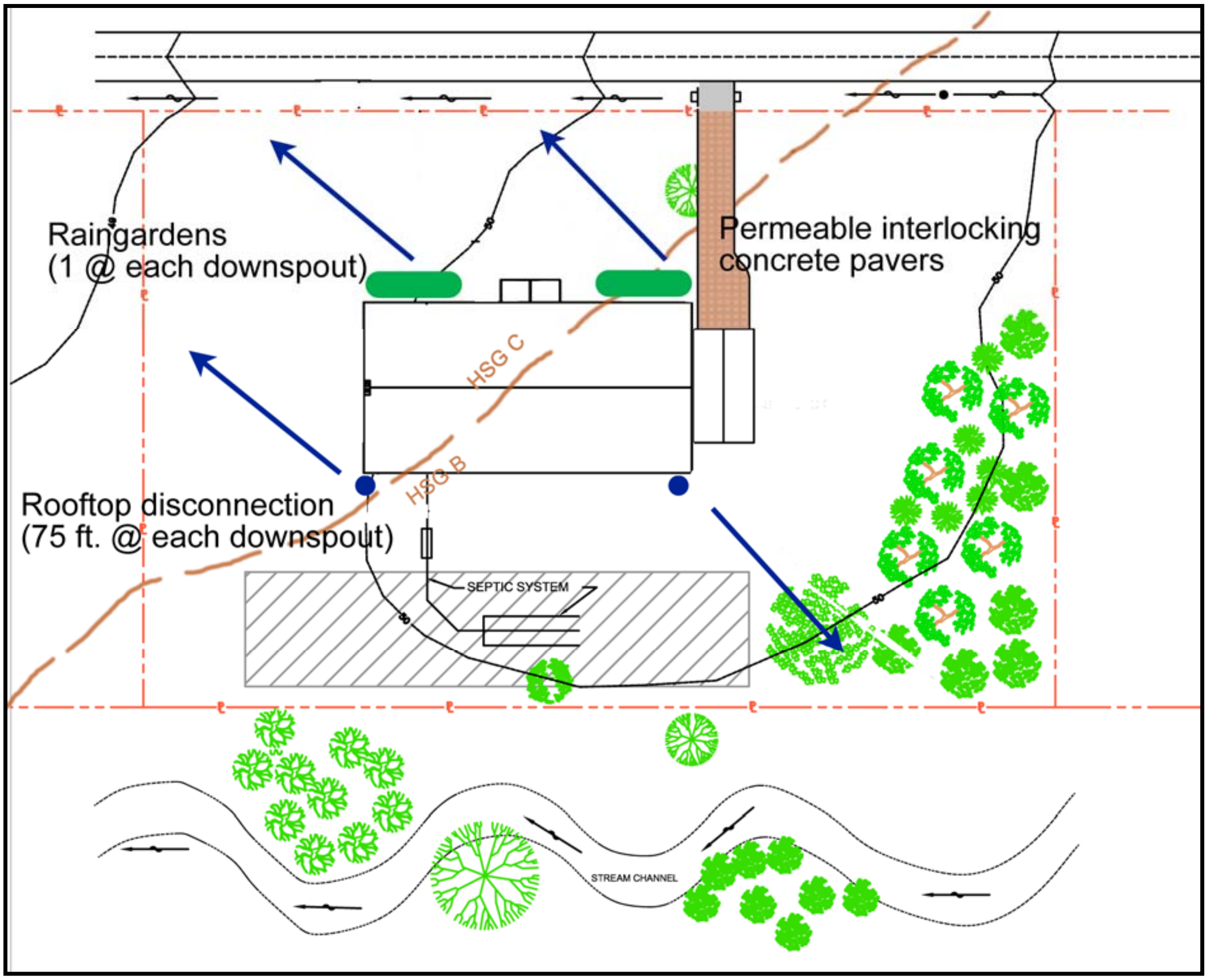
Even with the additional storage in the two raingardens, rain barrels located at each corner of the back of the house (DA to each = 1,725 ft^2) will be needed to capture an additional 10 ft^3 of runoff to fully meet the MEP standard. This means that the rain barrels need only capture 5 ft^3 at each corner to meet runoff reduction goals. Using the conversion factor of 1.0 ft^3 equals 7.5 gallons; this translates to 37.5 gallons of water that must be captured at each corner. While available in a range of shapes and sizes, most rain barrels typically hold 55 gallons (approx. 7 ft^3) of water. Therefore, one 55-gallon rain barrel located at each downspout on the back of the house will capture a total volume of 14 ft^3.

Step 5 – Design Assessment

After completing ESD practice design, the next step is to determine if the "woods in good condition" goals have been met. A summary of the practices used, and the area treated and rainfall and runoff volumes captured by each are:

Practice	Location	Area Treated	Volume (ESD_v)
Permeable Pavement	Driveway	1,000 ft^2	160 ft^3
Rooftop Disconnection	Front of House	3,450 ft^2	546 ft^3
Raingardens (2)	Front of House	3,450 ft^2	130 ft^3
Rain Barrels (6)	Back of House	3,450 ft^2	14 ft^3
		Total	850 ft^3
		ESD_v Req'd	845 ft^3

Fig. 3 Site Development Layout of ESD Practices and Techniques



The total volume captured and treated by the proposed design is 850 ft^3 which is greater than the target ESD_v. Using this volume, the area, and R_v for the entire site (40,000 ft^2 and 0.23, respectively), the rainfall captured and treated (P_E) may be determined as follows:

$$P_E = \frac{12 \times ESD_V}{R_V \times A} = \frac{12 \times 850\ ft^3}{0.23 \times 40{,}000\ ft^2} = 1.11\ inches$$

Using the combination of permeable pavement, rooftop disconnection, raingardens, and rain barrels (see Fig. 3), the design meets both the target P_E (1.1 inches) and ESD_v (845 ft^3) goals. Runoff has been reduced to reflect "woods in good condition" and ESD goals have been met. There are no additional management requirements and structural stormwater management practices are not needed.

Before submitting Site Development plans, the designs for the ESD practices should be completed. This includes any additional construction details and specifications needed to construct the permeable pavement and raingardens. Review agencies will determine if compliance with ESD to the MEP standard has been demonstrated.

Final Plan Design and Computations

Step 6 – Finalize ESD Design and Address Remaining Stormwater Requirements

After the Site Development plan approval, Final plans may be prepared that address any comments from the review agency. Because the proposed design addresses the MEP standard, additional structural practices are not necessary. Final construction drawings, hydrology and hydraulic computations, and final erosion and sediment control plans will be submitted at this time.

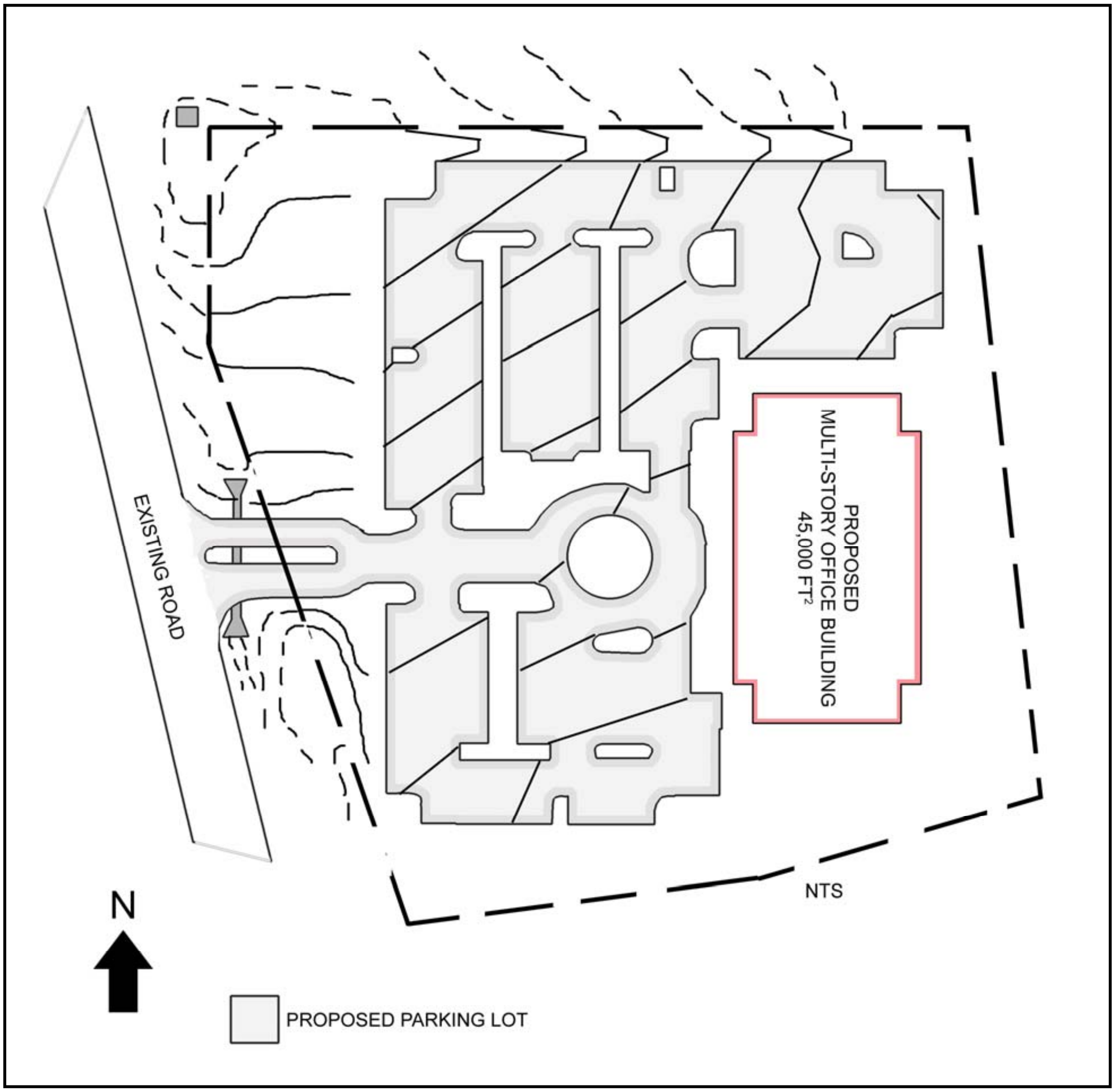
Discussion

The design example shown above is for a simple, single-lot project. However, the calculations used demonstrate the decisions that will be made in the design and review of more complicated ESD designs. In the next design example, ESD practices and techniques will be used singly and in series to capture and treat runoff from a larger, commercial development. While the second project is more complex, the steps taken to complete and review the design are the same for both examples.

Example No. 2 – Commercial Construction

The project for this example consists of a multi-story office building and parking lot. A sketch of the proposed site is shown in Figure 4.

Figure 4. Proposed Commercial Site



Concept Plan Design and Computations

The Concept Plan represents the first steps in a project's development and includes mapping of natural resources, initial project layout, and the preliminary design of ESD practices and techniques. During this phase, the designer demonstrates how ESD will be implemented to meet the MEP standard. The purpose is to show the review authorities that all opportunities for implementing ESD have been exhausted before proceeding with more detailed design.

Step 1 – Determine Stormwater Management Requirements

Initial Site Assessment (Site Data):

Existing Conditions

Total Drainage Area:	4.0 acres (174,240 ft^2)
Soil Types:	100% HSG B
Land Use:	Commercial

Proposed Layout

Impervious Cover:	3.2 acres (139,500 ft^2)
Building Size:	1.03 acres (45,000 ft^2)
Parking:	2.17 acres (94,633 ft^2)

Determine RCN's for Wooded Conditions:

The existing soils on site are all HSG B. Therefore, using the value from TR55 and shown in Table 5.3 for HSG B, the RCN for "woods in good condition" is 55.

Determine ESD Targets:

For this example, the proposed impervious area is 139,500 ft^2 and the total site area is 174,240 ft^2 (see above). Rainfall targets (see Table 5.3) for meeting ESD goals may be computed using the existing soils and impervious cover estimates from the initial site assessment (see above).

Compute Percent Imperviousness

$$I = \text{Impervious Area/Total Area}$$
$$= 139{,}500\ ft^2/174{,}240\ ft^2$$
$$= 80\%$$

Using I = 80%, the dimensionless volumetric runoff coefficient, R_v, may be calculated:

$$R_v = 0.05+0.009(I)$$
$$= 0.05+0.009(80)$$
$$= 0.77$$

By using Table 5.3 for HSG B and I = 80% as shown:

Hydrologic Soil Group B										
%I	RCN*	P_E = 1"	1.2"	1.4"	1.6"	1.8"	2.0"	2.2"	2.4"	2
0%	61									
5%	63									
10%	65									
15%	67	**55**								
20%	68	60	**55**	**55**						
25%	70	64	61	58						
30%	72	65	62	59	**55**					
35%	74	66	63	60	56					
40%	75	66	63	60	56					
45%	78	68	66	62	58					
50%	80	70	67	64	60					
55%	81	71	68	65	61	**55**				
60%	83	73	70	67	63	58				
65%	85	75	72	69	65	60	**55**			
70%	87	77	74	71	67	62	57			
75%	89	79	76	73	69	65	59			
80%	91	81	78	75	71	66	61			
85%	92	82	79	76	72	67	62	**55**		

A target of $P_E \geq 2.2$ inches will reduce the RCN to "woods in good condition."

The target P_E is 2.2 inches. An estimated ESD_v for the project is then calculated using this value:

$$\mathbf{ESD_V} = \frac{(P_E)(R_V)(A)}{12} = \frac{(2.2 \text{ inches})(0.77)(174{,}240 \text{ ft}^2)}{12} = 24{,}596.9 \text{ ft}^3$$

<u>Use 24,600 ft^3</u>

The target P_E and ESD_v are 2.2 inches and 24,600 ft^3, respectively.

Step 2 – Preliminary ESD Options

ESD requirements must be addressed for the entire limit of disturbance. This corresponds to an ESD_v of 24,600 ft^3 that must be captured and treated. To accomplish this, a combination of alternative surfaces, nonstructural techniques, and/or micro-scale practices will be used to treat the runoff from 2.2 inches of rainfall over the site. To facilitate the design process, the site has been divided into six different drainage areas (see Fig. 5). The proposed amount of imperviousness and landscaping within each area is shown in Table 2 below.

The site is moderately sloped (e.g., slopes > 5%) from the highpoint in the southeast corner to the lowpoint in the northwest. On-site soils are HSG B and groundwater was not encountered in any of the preliminary soil borings. Given the slopes and the proximity of the proposed development to the property lines, nonstructural techniques that disconnect runoff are not reasonable options. Conditions are favorable for using permeable pavements and infiltration practices. However, there are areas (e.g., the northwest corner) where significant grading is needed to level the site.

Figure 5. Commercial Layout with Proposed Drainage Areas

Table 2. Preliminary Drainage Area Information

Drainage (DA)	Impervious Area	Landscaped Area	Approx. %Site	Target ESD_v
1	24,500 ft^2	3,200 ft^2	16%	3,950 ft^3
2	20,000 ft^2	1,000 ft^2	12%	2,950 ft^3
3	15,000 ft^2	2,500 ft^2	10%	2,460 ft^3
4	13,000 ft^2	2,000 ft^2	9%	2,215 ft^3
5	17,000 ft^2	3,000 ft^2	12%	2,950 ft^3
6	5,000 ft^2	300 ft^2	3%	740 ft^3
Building	45,000 ft^2	---	26%	6,400 ft^3
Open Space	---	22,740 ft^2	13%	2,935 ft^2
∑	139,500 ft^2	34,740 ft^2	100%	24,600 ft^3

This will limit the use of infiltration. In these areas, filtering practices like micro-bioretention (M-6) and bio-swales (M-8) may be more appropriate.

As shown in Table 2, 61% of the site is graded so that water drains to landscaped features in the parking lot. The proposed building occupies an additional 26% of the site. The remaining 13% (22,740 ft^2) is the open space area along the northwest corner and southern edge of the site. Nonstructural techniques or micro-scale practices could be used to capture and treat runoff in these areas. However, final slopes in these areas will need to be too steep (e.g., 2:1) to meet the proposed grades. Using ESD to provide stormwater management in these areas will be very difficult. Therefore, for this particular design, the practices and techniques within DA's 1 – 6 and the building will be oversized where possible to over manage for these open areas.

Recognizing these conditions and constraints, the proposed concept design will use permeable pavements in the northeast quadrant of the site (DA's 1 & 2) and a green roof to cover 60% of the proposed building. Landscape infiltration practices will be used within the interior islands and along the northern and western perimeters of the site (see Figure 4) to manage runoff from the parking lot. Infiltration practices will be used to manage runoff from the building, too. In the remaining parking lot areas (DA's 3-6) where compacted fill precludes infiltration, either micro-bioretention or bio-swales will be used.

Step 3 – Preliminary Design

<u>Drainage Area (DA) 1</u>

Concept Design - Use Permeable Pavements (A-2):

The Concept plan indicates that there are five parking areas with a total of 63 individual spaces within DA-1 that could be surfaced with a permeable pavement. Given that a typical parking space is 162 ft^2 (9 ft. x 18 ft.), the total area of permeable pavement is 10,206 ft^2. The total area exceeds the 10,000 ft^2 limit for the design (A-2) found in Chapter 5. However, each of the individual areas is less than this limit and the Chapter 5 design for permeable pavements may be used. If the maximum subbase of 12 inches is used, then the effective RCN for these areas in HSG B soils is 55. Using Table 1 (see page 6 above), the treatment volume per square foot (ESD_v/ft^2) for this design is 0.196 ft^3 per square foot of pavement. Therefore, the volume of water captured and treated by the permeable pavements in DA-1 is:

$$\mathbf{0.196\,ft \times 10{,}206\,ft^2 = 2{,}000\,ft^3}$$

Concept Design – Use Landscape Infiltration (M-3):

The southern section of DA-1 is 12,000 ft^2 and its two interior islands have a combined surface area of 1,000 ft^2. The two islands are different sizes, and final grading may need to be adjusted to distribute runoff proportionately to each. However, for concept, it is sufficient to consider these two as one practice. The amount of rainfall captured in this area may be estimated initially using Equation 5.1 (Manual, p. 5.83) as follows:

$$P_E = 20\ \text{inches} \times \frac{1{,}000\ \text{ft}^2}{12{,}000\ \text{ft}^2} = 1.67\ \text{inches}$$

The land use within the area draining to these practices is a combination of imperviousness (6,654 ft^2), permeable pavement (5,346 ft^2), and open space (1,000 ft^2) and the percent imperviousness is approximately 52% (R_V = 0.52). The volume of water captured and treated within the landscape infiltration practice is:

$$V = \frac{(P)(R_V)(A)}{12} = \frac{(1.67\ \text{inch})(0.52)(13{,}000\ \text{ft}^2)}{12} = 941\ \text{ft}^3 \quad (\textit{Landscape Infiltration})$$

Concept Design – Use a Bio-Swale (M-8):

The remaining area (12,500 ft^2) of DA-1 drains to a long, narrow strip along the northern edge. Because there is some structural fill needed to bring this area to grade, infiltration practices should not be used. However, the configuration of this area is ideal for a bio-swale. The length of the swale is 275 ft. with a bottom width of 6 ft. for a surface area (A_f) of 1,650 ft^2. When considering just the area draining directly to it (12,500 ft^2), the amount of rainfall captured in the swale may be determined using Equation 5.2 (Manual, p. 5.98):

$$P_E = 15\ \text{inches} \times \frac{1{,}650\ \text{ft}^2}{12{,}500\ \text{ft}^2} = 1.98\ \text{inches}$$

The land use within the area draining to these practices is a combination of imperviousness (7,640 ft^2), permeable pavement (4,860 ft^2), and open space (1,650 ft^2) and the percent imperviousness is approximately 54% (R_V = 0.54). The volume of water captured and treated within the bio-swale is:

$$V = \frac{(P)(R_V)(A)}{12} = \frac{(1.98\ \text{inch})(0.54)(14{,}150\ \text{ft}^2)}{12} = 1{,}261\ \text{ft}^3 \quad (\textit{Bio-Swale})$$

The total volume of water captured and treated within DA-1 is:

$$2{,}000\ \text{ft}^3 + 941\ \text{ft}^3 + 1{,}261\ \text{ft}^3 = 4{,}202\ \text{ft}^3$$

This exceeds the target ESD_v (3,950 ft^2) for this drainage area by 252 ft^3.

Drainage Area (DA) 2

Concept Design - Use Permeable Pavements (A-2):

The Concept plan indicates that there are three parking areas with a total of 42 individual spaces within DA-2 that could be surfaced with a permeable pavement. Again, a typical parking space is 162 ft^2 (9 ft. x 18 ft.) and the total area of permeable pavement is 6,804 ft^2. If the maximum subbase of 12 inches is used, then the effective RCN for these areas in HSG B soils is 55. Using Table 1 (see p. 6), the treatment volume per square foot (ESD_v/ft^2) for this design is 0.196 ft^3 per square foot of pavement. Therefore, the volume of water captured and treated by the permeable pavements in DA-2 is:

$$\mathbf{0.196\,ft \times 6{,}804\,ft^2 = 1{,}334\,ft^3}$$

Concept Design – Use Micro-Bioretention (M-6):

The parking area of DA-2 will be graded to direct runoff to the internal, landscaped island. The soils are sandy (HSG B) but the total drainage area (20,000 ft^2) exceeds the maximum allowed for landscape infiltration practices. Therefore, the proposed design uses a micro-bioretention facility to capture and treat runoff from this section of the parking lot. The amount of rainfall captured by this design may be estimated initially using Equation 5.2 (Manual, p. 5.98) as follows:

$$\mathbf{P_E = 15\ inches \times \frac{1{,}000\ ft^2}{20{,}000\ ft^2} = 0.75\ inches}$$

The land use within the area draining to this practice is a combination of imperviousness (13,196 ft^2), permeable pavement (6,804 ft^2), and open space (1,000 ft^2) and the percent imperviousness is approximately 63% ($R_V = 0.62$). The volume of water captured and treated within the micro-bioretention practice is:

$$\mathbf{V = \frac{(P)(R_V)(A)}{12} = \frac{(0.75\ inch)(0.62)(21{,}500\ ft^2)}{12} = 833\ ft^3 \quad (\textit{Micro-Bioretention})}$$

The total volume of water captured and treated within DA-2 is:

$$\mathbf{1{,}334\,ft^3 + 833\,ft^3 = 2{,}167\,ft^3}$$

This is 783 ft^3 less than the target ESD_v (2,950 ft^3) for this drainage area.

Drainage Area (DA) 3

Concept Design – Use Micro-Bioretention (M-6):

The parking area within DA-3 (15,000 ft^3) will be graded to direct runoff to its western edge. While the soils are sandy, several feet of structural fill will be placed to bring this section of the site to the proposed grade. Because the subsoils will be compacted, permeable pavements and infiltration practices should not be used. Therefore, the proposed design uses a single micro-bioretention filter to capture and treat runoff from this section of the parking lot. The surface area of the proposed micro-bioretention filter is 2,500 ft^3. The amount of rainfall captured by this design may be estimated initially using Equation 5.2 as follows:

$$P_E = 15 \text{ inches} \times \frac{2{,}500 \text{ ft}^2}{15{,}000 \text{ ft}^2} = 2.5 \text{ inches}$$

The land use within the area draining to this practice is imperviousness (15,000 ft^2) and open space (2,500 ft^2) and the percent imperviousness is approximately 86% (R_V = 0.82). The volume of water captured and treated within the micro-bioretention practice is:

$$V = \frac{(P)(R_V)(A)}{12} = \frac{(2.5 \text{ inch})(0.82)(17{,}500 \text{ ft}^2)}{12} = 2{,}990 \text{ ft}^3 \quad (\textit{Micro – Bioretention})$$

This is 530 ft^3 more than the target ESD_v (2,460 ft^3) for this drainage area.

Drainage Area (DA) 4

Concept Design - Use Permeable Pavements (A-2):

The Concept plan indicates that there are three parking areas with a total of 30 individual spaces within DA-4 that could be surfaced with a permeable pavement for a total area of 4,860 ft^2. If the maximum subbase of 12 inches is used, then the effective RCN for these areas in HSG B soils is 55. Using Table 1 (see p. 6), the treatment volume per square foot (ESD_v/ft^2) for this design is 0.196 ft^3 per square foot of pavement. Therefore, the volume of water captured and treated by the permeable pavements in DA-1 is:

$$0.196 \text{ ft} \times 4{,}860 \text{ ft}^2 = 952 \text{ ft}^3$$

Concept Design – Use Micro-Bioretention (M-6):

The parking area within DA-4 (13,000 ft^3) also will be graded to direct runoff to its western edge. While the soils are sandy, the total drainage area (13,000 ft^2) exceeds the maximum allowed for landscape infiltration practices. Therefore, the proposed design uses a micro-bioretention facility to capture and treat runoff from this section of the parking lot. The surface area of the proposed micro-bioretention filter is 2,000 ft^3. The amount of rainfall captured by this design may be estimated initially using Equation 5.2 as follows:

$$P_E = 15 \text{ inches} \times \frac{2{,}000 \text{ ft}^2}{13{,}000 \text{ ft}^2} = 2.3 \text{ inches}$$

The land use within DA-4 is a combination of imperviousness (8,140 ft^2), permeable pavement (4,860 ft^2), and open space (2,000 ft^2) and the percent imperviousness is approximately 54% (R_V = 0.54). The volume of water captured and treated within the micro-bioretention practice is:

$$V = \frac{(P)(R_V)(A)}{12} = \frac{(2.3 \text{ inches})(0.54)(15{,}000 \text{ ft}^2)}{12} = 1{,}552 \text{ ft}^3 \quad (\textit{Micro – Bioretention})$$

The total volume of water captured and treated within DA-4 is:

$$952\,\text{ft}^3 + 1{,}552\,\text{ft}^3 = 2{,}504\,\text{ft}^3$$

This is 289 ft^3 more than the target ESD_v (2,215 ft^3) for this drainage area.

Drainage Area (DA) 5

Concept Design - Use Permeable Pavements (A-2):

The Concept plan indicates that there are three parking areas with a total of 27 individual spaces within DA-5 that could be surfaced with a permeable pavement for a total area of 4,374 ft^2. If the maximum subbase of 12 inches is used, then the effective RCN for these areas in HSG B soils is 55. Using Table 1 (see p. 6), the treatment volume per square foot (ESD_v/ft^2) for this design is 0.196 ft^3 per square foot of pavement. Therefore, the volume of water captured and treated by the permeable pavements in DA-5 is:

$$0.196\,\text{ft} \times 4{,}374\,\text{ft}^2 = 857\,\text{ft}^3$$

Concept Design – Use Landscape Infiltration (M-3):

The parking lot within DA-5 is 17,000 ft^2 and its three interior islands have a combined surface area of 3,000 ft^2. While they are different sizes, the area will be graded so that any overflow from the two interior islands will flow into the larger island along the western edge of the area. Therefore, for concept, it is sufficient to consider this "treatment train" as one practice. The amount of rainfall captured by this design may be estimated initially using Equation 5.1 (Manual, p. 5.83) as follows:

$$P_E = 20\text{ inches} \times \frac{3{,}000\,\text{ft}^2}{17{,}000\,\text{ft}^2} = 3.5\text{ inches}$$

The amount of rainfall that could be treated by these practices (3.5 inches) is greater than the amount of rainfall from the 1-year 24-hour storm (2.7 inches). Individual practices may be adjusted on a limited scale to over manage for smaller practices. However, the size of any practice is limited to the runoff from the 1-year 24-hour storm. Therefore, 2.7 inches of rainfall will be used to determine the volume of runoff captured by these landscape infiltration practices.

The land use within the area draining to these practices is a combination of imperviousness (12,626 ft^2), permeable pavement (4,374 ft^2), and open space (3,000 ft^2) and the percent imperviousness is approximately 63% ($R_V = 0.62$). The volume of water captured and treated within these landscape infiltration practices is:

$$V = \frac{(P)(R_V)(A)}{12} = \frac{(2.7\text{ inch})(0.62)(20{,}000\,\text{ft}^2)}{12} = 2{,}790\,\text{ft}^3 \quad (\textit{Landscape Infiltration})$$

The total volume of water captured and treated within DA-5 is:

$$\mathbf{857 ft^3 + 2,790 ft^3 = 3,647 ft^3}$$

This is 697 ft^3 more than the target ESD_v (2,950 ft^3) for this drainage area.

Drainage Area (DA) 6

Concept Design – Use Micro-Bioretention (M-6):

The entrance road and traffic circle comprising DA-6 will be graded to direct runoff along the curb and gutter to the circular landscaped area near the building. Soils are sandy, but this area is too close to the building to use infiltration. Therefore, the proposed design uses a micro-bioretention filter to capture and treat runoff. The surface area of the proposed micro-bioretention filter is 300 ft^3. The amount of rainfall captured by this design may be estimated initially using Equation 5.2 as follows:

$$\mathbf{P_E = 15\ inches \times \frac{300\ ft^2}{5,000\ ft^2} = 0.9\ inches}$$

The land use within the area draining to this practice is imperviousness (5,000 ft^2) and open space (300 ft^2) and the percent imperviousness is approximately 94% ($R_V = 0.90$). The volume of water captured and treated within the micro-bioretention practice is:

$$\mathbf{V = \frac{(P)(R_V)(A)}{12} = \frac{(0.9\ inches)(0.90)(5,300\ ft^2)}{12} = 358\ ft^3 \quad (\textit{Micro-Bioretention})}$$

This is 382 ft^3 less than the target ESD_v (740 ft^3) for this drainage area.

Proposed Building

Concept Design – Use Green Roof (A-1):

The initial design of the building has a flat roof and is ideal for using a green roof. However, only 60% of the rooftop area (27,000 ft^2) will be surfaced with a green roof to allow room for other building infrastructure (e.g., air conditioning, telecommunications). Table 5.4 (Manual, p. 5.42) lists the effective RCNs for green roofs with thicknesses ranging from 2 to 8 inches. Using this table, a 6-inch green roof has effective RCNs of 85. Using Table 1 (see p. 6), this is equivalent to capturing 1.14 inches of runoff (0.095 ft) over the surface of the practice. Therefore, the volume of water captured and treated within the proposed green roof is:

$$\mathbf{0.095 ft \times 27,000 ft^2 = 2,565 ft^3}$$

This is 3,835 ft^3 less than the target ESD_v (6,400 ft^3) for this drainage area.

Concept Design – Use Micro-Bioretention (M-6):

The proposed green roof alone is insufficient to address ESD goals for the proposed building and additional practices will be needed. At this stage of the design, there is an estimated 650 linear feet of space around the building's perimeter that could be used for a series of 6-foot wide micro-bioretention practices. Using a combined surface area of 3,900 ft^2, the amount of rainfall captured by this design may be estimated initially using Equation 5.2 as follows:

$$P_E = 15 \text{ inches} \times \frac{3{,}900 \text{ ft}^2}{45{,}000 \text{ ft}^2} = 1.3 \text{ inches}$$

The land use within the area draining to this practice is a combination of imperviousness (18,000 ft^2), green roof (27,000 ft^2), and open space (3,900 ft^2) and the percent imperviousness is approximately 37% ($R_V = 0.38$). The volume of water captured and treated by this micro-bioretention practice is:

$$V = \frac{(P)(R_V)(A)}{12} = \frac{(1.3 \text{ inch})(0.38)(48{,}900 \text{ ft}^2)}{12} = 2{,}013 \text{ ft}^3 \quad (\textit{Micro-Bioretention})$$

The combined volume of runoff captured and treated by the green roof (2,565 ft^3) and the micro-bioretention system (2,013 ft^3) is 4,578 ft^3. This is still less than the 6,400 ft^3 needed to address ESD goals for the building.

Preliminary Design Assessment

The requirements for the proposed design were to capture the runoff from at least 2.2 inches of rainfall across the site. This equated to an ESD_v of 24,600 ft^3 of runoff that must be captured and treated. The total volume of runoff captured by the proposed Concept design is:

Table 3. Preliminary Design Assessment Information

Drainage (DA)	Target ESD_v	Actual ESD_v
1	3,950 ft^3	4,202 ft^3
2	2,950 ft^3	2,167 ft^3
3	2,460 ft^3	2,990 ft^3
4	2,215 ft^3	2,504 ft^3
5	2,950 ft^3	3,647 ft^3
6	740 ft^3	358 ft^3
Building	6,400 ft^3	4,578 ft^3
Open Space	2,935 ft^3	0 ft^3
$\sum$	24,600 ft^3	20,446 ft^3

The total volume captured across the site (20,446 ft^3) is 4,154 ft^3 less than the target ESD_v (24,600 ft^3), and the Concept design falls short of meeting ESD goals. It may be possible to capture an additional 4,000 ft^3 of runoff by adjusting the dimensions of individual practices.

However, more detailed ESD design is difficult as much of the specific information needed to support three-dimensional design is not available at this stage of the project. This is an option that will be explored as the design progresses and more details are available.

At this point, the designer may wish to submit Concept plans after completing these steps. The plans must include all documentation needed to demonstrate that the proposal is feasible, that all opportunities for using ESD practices and techniques have been evaluated, and that the shortage may be addressed in the next design phase. At this time, the project may proceed forward if, in the judgment of the plan review authorities, the proposal is feasible and compliance with the MEP standard will be addressed.

Site Development Plan Design and Computations

The Site Development plan provides more details and computations as the design progresses towards the final stages and more information about the site design is available. Any comments from the review agency on the Concept plan should be addressed and the details, dimensions, and locations of ESD practices are provided at this stage. Also, the final designs of each ESD practice identified in the Concept plan should be completed.

In addition to completing the individual design of each ESD practice used, concerns raised by the review agency must be addressed. While there are many comments that might apply to this example, the most obvious is that treatment of the required ESD_v was not achieved. Therefore, the design should be re-evaluated to ensure that all reasonable opportunities for implementing ESD to the MEP have been exhausted. As discussed in Step 2 (Preliminary ESD Options) above, the original concept was to adjust the practices and techniques within DA's 1 – 6 and the building where possible to overmanage for the open areas and fully capture the ESD_v. As more details about the overall site design (e.g., infrastructure location, final grades) become available, the dimensions of each ESD practice may be adjusted to capture additional runoff. If the required ESD_v cannot be captured after increasing the dimensions of each practice as much as is practical, any remaining volume will be treated using a structural practice.

Step 4 – ESD Practice Design

The Concept plan fell short of addressing ESD requirements by capturing and treating a portion of the ESD_v (24,600 ft^3) in a combination of alternative surfaces and micro-scale practices distributed throughout six drainage areas and the building. However, ESD_v was not completely captured and it is questionable if ESD to the MEP has been addressed. The original Concept plan included adjusting each of the micro-scale practices to overmanage for off site areas where addressing ESD was not practical. While the surface area of each practice was maximized during the Concept phase, altering other dimensions (e.g., filter bed depth, ponding depth) will be investigated during this phase.

Drainage Area (DA) 1

Concept Plan Design Information	
ESD Practice	Treatment Volume
Permeable Pavements	2,000 ft^3
Landscape Infiltration	941 ft^3
Bio-Swale	1,261 ft^3
$\sum$	4,202 ft^3
Target ESD_v	3,950 ft^3

Site Development Design – Permeable Pavements (A-2):

The permeable pavements as proposed on the Concept plan will not be changed in the Site Development phase. A more complete design, including cross-sections and details will be provided as part of the Site Development plans. The permeable pavements in DA-1 will capture and treat 2,000 ft^3 of runoff.

Site Development Design –Landscape Infiltration (M-3):

As described in the Concept plan, the two landscape infiltration practices in DA-1 have a combined surface area of 1,000 ft^2 and runoff is distributed proportionately to each. While separate details and cross-sections must be provided for each, for this example it is sufficient to consider these two as one practice. Also, the size of any practice is limited to the runoff from the 1-year 24-hour storm draining to it. Therefore, these practices can only be oversized to capture the runoff from 2.7 inches of rainfall. In the Concept design phase, it was established that the percent imperviousness within the subject area is 52% (R_v = 0.52). Therefore, the maximum amount of runoff that can be captured by these practices is:

$$V = \frac{(P)(R_V)(A)}{12} = \frac{(2.7\text{ inch})(0.52)(13{,}000\text{ ft}^2)}{12} = 1{,}521\text{ ft}^3 \quad (\textit{Landscape Infiltration})$$

Each landscape infiltration practice will have a 0.5-foot temporary ponding depth. Each will also have a 1-foot thick planting soil layer, a 1-foot thick gravel layer, and a 1.0 foot thick sand "bridging" layer (total = 3.0 feet). Given that the porosity (n) for the soil, sand, and gravel layers is 0.4, the total combined storage within these practices is:

$$\underbrace{(1{,}000\text{ ft}^2 \times 0.5\text{ ft})}_{\textit{ponding depth}} + \underbrace{[0.4 \times (1{,}000\text{ ft}^2 \times 3.0\text{ ft})]}_{\textit{storage w/in practice}} = 1{,}700\text{ ft}^3$$

Because this exceeds the amount of runoff from the 1-year 24-hour storm, the lesser of the two volumes must be used when assessing compliance with the MEP standard. Therefore, the volume of runoff that is captured by the combined landscape infiltration practices is 1,521 ft^2.

Site Development Design – Bio-Swale (M-8):

As described in the Concept plan, the remaining area (12,500 ft^2) of DA-1 drains to a long, narrow strip along the northern edge. After more detailed design, the length of this swale is still 275 ft. but the bottom width is reduced to 5 ft. to keep the practice within the property limits. The revised surface area (A_f) is 1,375 ft^2. The temporary ponding depth for the swale is 0.5 ft and the filter media layer is 2 feet deep. Given that the porosity (n) for the filter media is 0.4, the total combined storage within this practice is:

$$\underbrace{(1{,}375\ \text{ft}^2 \times 0.5\ \text{ft})}_{\textit{ponding depth}} + \underbrace{[0.4 \times (1{,}375\ \text{ft}^2 \times 2.0\ \text{ft})]}_{\textit{storage w/in practice}} = 1{,}788\ \text{ft}^3$$

When considering that the area (12,500 ft^2 + 1,375 ft^2 = 13,875 ft^2) draining to it has a percent imperviousness of 55% (R_v = 0.54), the maximum amount of runoff that can be captured by these practices is:

$$V = \frac{(P)(R_V)(A)}{12} = \frac{(2.7\ \text{inch})(0.54)(13{,}875\ \text{ft}^2)}{12} = 1{,}685\ \text{ft}^3 \quad (\textit{Bio-Swale})$$

Because the amount of runoff that can be stored within the bio-swale (1,788 ft^3) exceeds the amount of runoff from the 1-year 24-hour storm, the lesser of the two volumes must be used when assessing compliance with the MEP standard. Therefore, the volume of runoff that is captured by the bio-swale is 1,685 ft^3.

Factoring in the storage provided in the permeable pavements (see above), the total volume of water captured and treated within DA-1 is:

$$2{,}000\ \text{ft}^3 + 1{,}521\ \text{ft}^3 + 1{,}685\ \text{ft}^3 = 5{,}206\ \text{ft}^3$$

This exceeds the target ESD_v (3,950 ft^3) for this drainage area by 1,290 ft^3.

Site Development Plan Design Information		
ESD Practice	Concept Volume	Site Development Volume
Permeable Pavements	2,000 ft^3	2,000 ft^3
Landscape Infiltration	941 ft^3	1,521 ft^3
Bio-Swale	1,261 ft^3	1,685 ft^3
∑	4,202 ft^3	5,206 ft^3
Target ESD_v	3,950 ft^3	

Drainage Area (DA) 2

Concept Plan Design Information	
ESD Practice	Treatment Volume
Permeable Pavements	1,334 ft^3
Micro-Bioretention	833 ft^3
∑	2,167 ft^3
Target ESD_v	2,950 ft^3

Site Development Design – Permeable Pavements (A-2):

The permeable pavements as proposed on the Concept plan will not be changed in the Site Development phase. A more complete design, including cross-sections and details will be provided as part of the Site Development plans. The permeable pavements in DA-2 will capture and treat 1,334 ft^3 of runoff.

Site Development Design – Micro-Bioretention (M-6):

As described in the Concept plan, the parking area of DA-2 is graded to direct runoff to the internal, landscaped island. This practice has a surface area of 1,000 ft^2 and is designed with a 1-foot temporary ponding depth and a 2-foot thick filter media layer. Given that the porosity (*n*) for the media layer is 0.4, the total combined storage within this practice is:

$$\underbrace{(1{,}000\ ft^2 \times 1.0\ ft)}_{\textit{ponding depth}} + \underbrace{[0.4 \times (1{,}000\ ft^2 \times 2.0\ ft)]}_{\textit{storage w/in media}} = 1{,}800\ ft^3$$

When considering that the area (21,000 ft^2) draining to it has a percent imperviousness of 63% (R_v = 0.62), the maximum amount of runoff that can be captured by these practices is:

$$V = \frac{(P)(R_V)(A)}{12} = \frac{(2.7\ inch)(0.62)(21{,}000\ ft^2)}{12} = 2{,}930\ ft^3 \quad (\textit{Micro-Bioretention})$$

The storage volume within the proposed micro-bioretention area is less than the amount of runoff from the 1-year 24-hour storm. Factoring in the storage provided in the permeable pavements (see above), the total volume of water captured and treated within DA-2 is:

$$1{,}334\ ft^3 + 1{,}800\ ft^3 = 3{,}134\ ft^3$$

This exceeds the target ESD_v (2,950 ft^3) for this drainage area by 184 ft^3.

Site Development Plan Design Information		
ESD Practice	Concept Volume	Site Development Volume
Permeable Pavements	1,334 ft^3	1,334 ft^3
Micro-Bioretention	833 ft^3	2,930 ft^3
$\sum$	2,167 ft^3	3,134 ft^3
Target ESD_v	2,950 ft^3	

Drainage Area (DA) 3

Concept Plan Design Information	
ESD Practice	Treatment Volume
Micro-Bioretention	2,990 ft^3
Target ESD_v	2,460 ft^3

Site Development Design – Micro-Bioretention (M-6):

According to the Concept plan, the estimated storage volume of the micro-bioretention practice in DA-3 is 2,990 ft^3. Given that DA-3 is 17,500 ft^2 and 86% impervious ($R_v = 0.82$), the maximum volume of water that can be captured in the practice is:

$$V = \frac{(P)(R_V)(A)}{12} = \frac{(2.7\ \text{inch})(0.82)(17{,}500\ ft^2)}{12} = 3{,}229\ ft^3 \quad (\textit{Micro-Bioretention})$$

This micro-bioretention practice has a surface area of 2,500 ft^2 and is designed with a 0.5-foot temporary ponding depth and a 2-foot thick filter media layer. Given that the porosity (*n*) for the media layer is 0.4, the total combined storage within this practice is:

$$\underbrace{(2{,}500\ ft^2 \times 0.5\ ft)}_{\text{ponding depth}} + \underbrace{[0.4 \times (2{,}500\ ft^2 \times 2.0\ ft)]}_{\text{storage w/in media}} = 3{,}250\ ft^3$$

The storage volume within the proposed micro-bioretention area exceeds the amount of runoff from the 1-year 24-hour storm, and the lesser volume will be used. Therefore, the total volume of water captured and treated within DA-3 is 3,229 ft^3 which exceeds the target ESD_v (2,460 ft^3) for the drainage area by 769 ft^3.

Site Development Plan Design Information		
ESD Practice	Concept Volume	Site Development Volume
Micro-Bioretention	2,990 ft^3	3,229 ft^3
Target ESD_v	2,460 ft^3	

Drainage Area (DA) 4

Concept Plan Design Information	
ESD Practice	Treatment Volume
Permeable Pavements	952 ft^3
Micro-Bioretention	1,552 ft^3
$\sum$	2,504 ft^3
Target ESD_v	2,215 ft^3

Site Development Design – Permeable Pavements (A-2):

The permeable pavements as proposed on the Concept plan will not be changed in the Site Development phase. A more complete design, including cross-sections and details will be provided as part of the Site Development plans. The permeable pavements in DA-4 will capture and treat 952 ft^3 of runoff.

Site Development Design – Micro-Bioretention (M-6):

According to the Concept plan, the estimated storage volume of the micro-bioretention practice in DA-4 is 1,552 ft^3. Given that DA-4 is 15,000 ft^2 and 54% impervious ($R_v = 0.54$), the maximum volume of water that can be captured in the practice is:

$$V = \frac{(P)(R_V)(A)}{12} = \frac{(2.7\text{ inch})(0.54)(15{,}000\text{ ft}^2)}{12} = 1{,}822\text{ ft}^3 \quad (\textit{Micro-Bioretention})$$

This micro-bioretention practice has a surface area of 2,000 ft^2 and is designed with a 0.5-foot temporary ponding depth and a 2-foot thick filter media layer. Given that the porosity (n) for the media layer is 0.4, the total combined storage within this practice is:

$$\underbrace{(2{,}000\text{ ft}^2 \times 0.5\text{ ft})}_{\textit{ponding depth}} + \underbrace{[0.4 \times (2{,}000\text{ ft}^2 \times 2.0\text{ ft})]}_{\textit{storage w/in media}} = 2{,}600\text{ ft}^3$$

The storage volume within the proposed micro-bioretention area exceeds the amount of runoff from the 1-year 24-hour storm, and the lesser volume will be used. Factoring in the amount of runoff captured within the permeable pavements (952 ft^3), the total volume of water captured and treated within DA-4 is 2,774 ft^3 which exceeds the target ESD_v (2,215 ft^3) for the drainage area by 559 ft^3.

Site Development Plan Design Information		
ESD Practice	Concept Volume	Site Development Volume
Permeable Pavements	952 ft^3	952 ft^3
Micro-Bioretention	1,552 ft^3	1,822 ft^3
$\sum$	2,504 ft^3	2,774 ft^3
Target ESD_v	2,215 ft^3	

Drainage Area (DA) 5

Concept Plan Design Information	
ESD Practice	Treatment Volume
Permeable Pavements	857 ft^3
Landscape Infiltration	2,790 ft^3
$\sum$	3,647 ft^3
Target ESD_v	2,950 ft^3

Site Development Design – Permeable Pavements (A-2):

The permeable pavements as proposed on the Concept plan will not be changed in the Site Development phase. A more complete design, including cross-sections and details will be provided as part of the Site Development plans. The permeable pavements in DA-5 will capture and treat 857 ft^3 of runoff.

Site Development Design – Landscape Infiltration (M-3):

According to the Concept plan, the estimated volume of water captured by the landscape infiltration practices within DA-5 exceeded the runoff from the 1-year, 24-hour storm, and the lesser volume (2,790 ft^3) was applied to the assessment of the MEP standard. Because the design is already maximized, no further adjustment of these practices can be done. Therefore, the minimum dimensions for landscape infiltration practices will be used. The combined surface area of these practices is 3,000 ft^2. Each landscape infiltration practice will have a 0.5-foot temporary ponding depth, a 1-foot thick planting soil layer, a 1-foot thick gravel layer, and a 1.0 foot thick sand "bridging" layer (total = 3.0 feet). Given that the porosity (n) for the soil, sand, and gravel layers is 0.4, the total combined storage within these practices is:

$$\underbrace{(3{,}000\ ft^2 \times 0.5\ ft)}_{\textit{ponding depth}} + \underbrace{[0.4 \times (3{,}000\ ft^2 \times 3.0\ ft)]}_{\textit{storage w/in practice}} = 5{,}100\ ft^3 \quad (\textit{Landscape Infiltration})$$

Factoring in the amount of runoff captured within the permeable pavements (857 ft^3, see Concept design), the total volume of water captured and treated within DA-5 is 3,647 ft^3 which exceeds the target ESD_v (2,950 ft^3) for the drainage area by 697 ft^3.

Site Development Plan Design Information		
ESD Practice	Concept Volume	Site Development Volume
Permeable Pavements	857 ft^3	857 ft^3
Landscape Infiltration	2,790 ft^3	2,790 ft^3
$\sum$	3,647 ft^3	3,647 ft^3
Target ESD_v	2,950 ft^3	

Drainage Area (DA) 6

Concept Plan Design Information	
ESD Practice	Treatment Volume
Micro-Bioretention	358 ft^3
Target ESD_v	740 ft^3

Site Development Design – Micro-Bioretention (M-6):

On the Concept plan, the entrance road and traffic circle were graded to direct runoff to the circular landscaped area using curb and gutter. A micro-bioretention filter with a surface area of 300 ft^2 will address ESD requirements because this landscaped area is too close to the building for infiltration practices to be used. Because it is at the upstream end of the proposed storm drainage system, the underdrains will need to be placed as close to the surface as possible. This limits the thickness of the filter media to the 2 foot minimum. A 0.5-foot surface ponding will be used to further limit the depth of this practice. The porosity (n) of the filter media is 0.4, and total storage volume of the micro-bioretention practice is:

$$\underbrace{(300\ ft^2 \times 0.5\ ft)}_{\textit{ponding depth}} + \underbrace{[0.4 \times (300\ ft^2 \times 2.0\ ft)]}_{\textit{storage w/in media}} = 390\ ft^3 \quad (\textit{Micro – Bioretention})$$

This storage volume is 350 ft^3 less than the target ESD_v (740 ft^3) for this drainage area.

Site Development Plan Design Information		
ESD Practice	Concept Volume	Site Development Volume
Micro-Bioretention	358 ft^3	390 ft^3
Target ESD_v	740 ft^3	

Proposed Building

Concept Plan Design Information	
ESD Practice	Treatment Volume
Green Roof	2,565 ft^3
Micro-Bioretention	2,013 ft^3
$\sum$	4,578 ft^3
Target ESD_v	6,400 ft^3

Site Development Design – Green Roof (A-1):

The green roof design as proposed on the Concept plan will not be changed in the Site Development phase. A more complete design, including cross-sections and details will be provided as part of the Site Development plans. The proposed green roof over 60% of the building roof will capture and treat 2,565 ft^3 of runoff.

Site Development Design – Micro-Bioretention (M-6):

The original concept proposed a green roof and a series of micro-bioretention practices around the building's perimeter to capture and treat runoff from the rooftop area. The preliminary design estimated that these micro-bioretention systems would be 6 feet wide with a combined length of 650 feet. A more detailed design of the building limits the width of these practices to 3 feet and the available area around the building's perimeter is reduced from 650 feet to 450 feet. Because they are adjacent to the building, these practices will be designed as raised planters that discharge to the surface. In light of this, the vertical impact of these practices will need to be minimal. To accomplish this, the minimum filter media depth will be used in their design. Considering these factors, the micro-bioretention "planters" along the building perimeter will be 5 feet wide with ponding and filter media depths of 0.5 feet and 2 feet respectively. Using a combined length of 450 feet (total surface area = 1,350 ft^2) and a porosity of 0.4, the total storage volume in these practices is:

$$\mathbf{(1{,}350\ ft^2 \times 0.5\ ft) + [0.4 \times (1{,}350\ ft^2 \times 2.0\ ft)] = 1{,}755\ ft^3} \quad (\textbf{\textit{Micro – Bioretention}})$$

ponding depth ***storage w/in media***

Factoring in the amount of runoff captured within the green roof (2,565 ft^3), the total volume of water captured and treated from the building is 4,320 ft^3. This is 2,080 ft^3 less than the target ESD_v (6,400 ft^3).

Site Development Plan Design Information		
ESD Practice	Concept Volume	Site Development Volume
Green Roof	2,565 ft^3	2,565 ft^3
Micro-Bioretention	2,013 ft^3	1,755 ft^3
$\sum$	4,578 ft^3	4,320 ft^3
Target ESD_v	6,400 ft^3	

Step 5 – Design Assessment

○ **Determine if ESD Targets are Met:** After completing ESD practice design, the next step is to determine if the "woods in good condition" goals have been met. A summary of the individual drainage areas, practices used, area treated, and runoff volumes captured by each are shown in Table 4 below:

Table 4. Site Development Summary

Drainage Area	Practice	Dimensions	Area Treated	Volume (ESD_v)
DA-1	Permeable Pavement (A-2)	Area = 10,206 ft^2 subbase = 12 inches	---	2,000 ft^3
	Landscape Infiltration (M-3)	1,000 ft^2 x 3 ft w/0.5 ft ponding	12,000 ft^2	1,521 ft^3*
	Bio-Swale (M-8)	1,375 ft^2 x 2 ft w/0.5 ft ponding	12,500 ft^2	1,719 ft^3*
DA-2	Permeable Pavement (A-2)	Area = 6,804 ft^2 subbase = 12 inches	---	1,334 ft^3
	Micro-Bioretention (M-6)	1,000 ft^2 x 2 ft w/1 ft ponding	20,000 ft^2	1,800 ft^3
DA-3	Micro-Bioretention (M-6)	2,500 ft^2 x 2 ft w/0.5 ft ponding	15,000 ft^2	3,229 ft^3*
DA-4	Permeable Pavement (A-2)	Area = 4,860 ft^2 subbase = 12 inches	---	952 ft^3
	Micro-Bioretention (M-6)	2,000 ft^2 x 2 ft w/0.5 ft ponding	15,000 ft^2	1,822 ft^3
DA-5	Permeable Pavement (A-2)	Area = 4,374 ft^2 subbase = 12"	---	857 ft^3
	Landscape Infiltration (M-3)	3,000 ft^2 x 3 ft w/0.5 ft ponding	17,000 ft^2	3,647 ft^3*
DA-6	Micro-Bioretention (M-6)	300 ft^2 x 2 ft w/0.5 ft ponding	5,000 ft^2	390 ft^3
Building	Green Roof (A-1)	27,000 ft^2 thickness = 6 inches	---	2,565 ft^3
	Micro-Bioretention (M-6)	1,350 ft^2 x 2 ft w/0.5 ft ponding	45,000 ft^2	1,755 ft^2
			Total	23,591 ft^3
			ESD_v Req'd	24,600 ft^3

*NOTE: Volume of runoff captured by the practice exceeded the amount of runoff from the 1-year storm. The ESD_v reflects the runoff from the 1-year storm.

The total volume captured and treated by the proposed design, 23,591 ft^3, is less than the target ESD_v, 24,600 ft^3. Using the volume captured and treated by the proposed design, the total site area, and R_v for the entire site (174,240 ft^2 and 0.77, respectively), the rainfall captured and treated (P_E) may be determined as follows:

$$P_E = \frac{12 \times ESD_V}{R_V \times A} = \frac{12 \times 23{,}591\,ft^3}{0.77 \times 174{,}240\,ft^2} = 2.1\,inches$$

○ **Evaluate Additional ESD Opportunities:** Because the required ESD_v has not been met, the project must be re-evaluated to determine if additional ESD measures can be implemented reasonably. For this example, it is assumed that the review agency agrees that all reasonable efforts to implement ESD to the MEP have been exhausted. Because the ESD targets have not been met, structural practices (see the Manual, Chapter 3) will be used to address the remaining management requirements.

○ **Determine Additional Management Requirements:** When structural practice are necessary, the original percent imperviousness and the amount of rainfall treated by the proposed design (P_E = 2.1 inches) are used in conjunction with Table 5.3 to determine the reduced RCN.

Hydrologic Soil Group B										
%I	RCN*	P_E = 1"	1.2"	1.4"	1.6"	1.8"	2.0"	2.2"	2.4"	2.6"
0%	61									
5%	63									
10%	65									
15%	67	**55**								
20%	68	60	**55**	**55**						
25%	70	64	61	58						
30%	72	65	62	59	**55**					
35%	74	66	63	60	56					
40%	75	66	63	60	56					
45%	78	68	66	62	58					
50%	80	70	67	64	60					
55%	81	71	68	65	61	**55**				
60%	83	73	70	67	63	58				
65%	85	75	72	69	65	60	**55**			
70%	87	77	74	71	67	62	57			
75%	89	79	76	73	69	65	59			
80%	91	81	78	75	71	60	61			
85%	92	82	79	76	72	67	62	**55**		
90%	94	84	81	78	74	70	65	59	**55**	
95%	96	87	84	81	77	73	69	63	57	
100%	98	89	86	83	80	76	72	66	59	**55**

Because the P_E (2.1 inches) is not shown on Table 5.3, the next lower value, 2.0 inches, is used to determine the reduced RCN. The 1-year, 24-hour design storm for this project is 2.7 inches. Using SCS curve number methodology, the runoff (Q_E) from the proposed project may be calculated as:

$$Q_E = \frac{(P_1 - 0.2S)^2}{(P_1 + 0.8S)}$$

where Q_E = runoff (inches)
P_1 = rainfall (inches) for the 1-year design storm; (for this example, P = 2.7 inches)
S = (1000/RCN) – 10; for RCN of 61, S = 6.39 and for RCN of 55, S = 8.18

The 1-year runoff associated with an RCN of 61 is:

$$Q_E = \frac{(P_1 - 0.2S)^2}{(P_1 + 0.8S)} = \frac{[2.7\text{ inches} - (0.2 \times 6.39)]^2}{[2.7\text{ inches} + (0.8 \times 6.39)]} = \frac{2.022}{7.822} = 0.26\text{ inches}$$

The volume of runoff from the proposed project for an RCN of 61 is:

$$V = \frac{Q_E \times A}{12} = \frac{0.26\ \text{inches} \times 174{,}240\ \text{ft}^2}{12} = 3{,}775\ \text{ft}^3$$

The 1-year runoff associated with an RCN of 55 is:

$$Q_1 = \frac{(P_1 - 0.2S)^2}{(P_1 + 0.8S)} = \frac{[2.7\ \text{inches} - (0.2 \times 8.18)]^2}{[2.7\ \text{inches} + (0.8 \times 8.18)]} = \frac{1.132}{9.244} = 0.12\ \text{inches}$$

The volume of runoff from the proposed project for an RCN of 55 is:

$$V = \frac{Q_1 \times A}{12} = \frac{0.12\ \text{inches} \times 174{,}240\ \text{ft}^2}{12} = 1{,}742\ \text{ft}^3$$

The runoff that must be captured and treated in a structural practice is:

$$3{,}775\ \text{ft}^3 - 1{,}742\ \text{ft}^3 = 2{,}033\ \text{ft}^3$$

○ **Design Structural Practices if Necessary:** Any structural practice(s) needed to address the difference in runoff are located on the Site Development plan and designed according to the criteria found in Chapter 3 of the Manual. In this example, an infiltration trench located in the northwest corner of the site will capture and treat the remaining 1,742 ft^3 of runoff needed to meet ESD goals. Using the methods found in Chapter 3 and Appendix D.13 for the design of infiltration trenches, the required surface area of the trench (A_t) may be determined as follows:

$$A_t = \frac{V_w}{nd_t + fT}$$

where A_t = area of the trench (ft^2)
V_w = design volume; in this case 2,033 ft^3
n = porosity of the stone reservoir, or 0.4
d_t = depth of the trench, for this design, use 5.0 ft
f = soil infiltration rate, use 0.52 in/hr for HSG B
T = effective time to fill the trench, use 2 hours
Using these values, the minimum area of the infiltration trench is:

$$A_t = \frac{V_w}{nd_t + fT} = \frac{2{,}033\ \text{ft}^3}{(0.4 \times 5.0\ \text{ft}) + (0.52 \times 2)} = 669\ \text{ft}^2$$

A 15 ft. by 45 ft. by 5 ft. deep infiltration trench will address the remaining stormwater management requirements.

○ **Complete Design:** Before submitting the Site Development plans, the designs for all of the ESD techniques and practices should be completed. This includes all pertinent details, standards, and specifications needed to verify that the designs are in accordance with the requirements found in Chapter 5. Likewise, computations must be submitted that demonstrate compliance with the ESD standard at this time. Review agencies will confirm that ESD has been implemented to the MEP prior to allowing the use of structural practices to address remaining requirements.

Final Plan Design and Computations

Step 6 – Finalize ESD Design and Address Remaining Stormwater Requirements

After the Site Development plan approval, Final plans may be prepared that address any comments from the review agency. Because the proposed design fell short of the MEP standard, an additional structural practice was necessary to meet remaining stormwater management requirements. The final construction drawings for all of the stormwater practices, including the proposed infiltration trench, all hydrology and hydraulic computations, and the final erosion and sediment control plans will be submitted at this time.