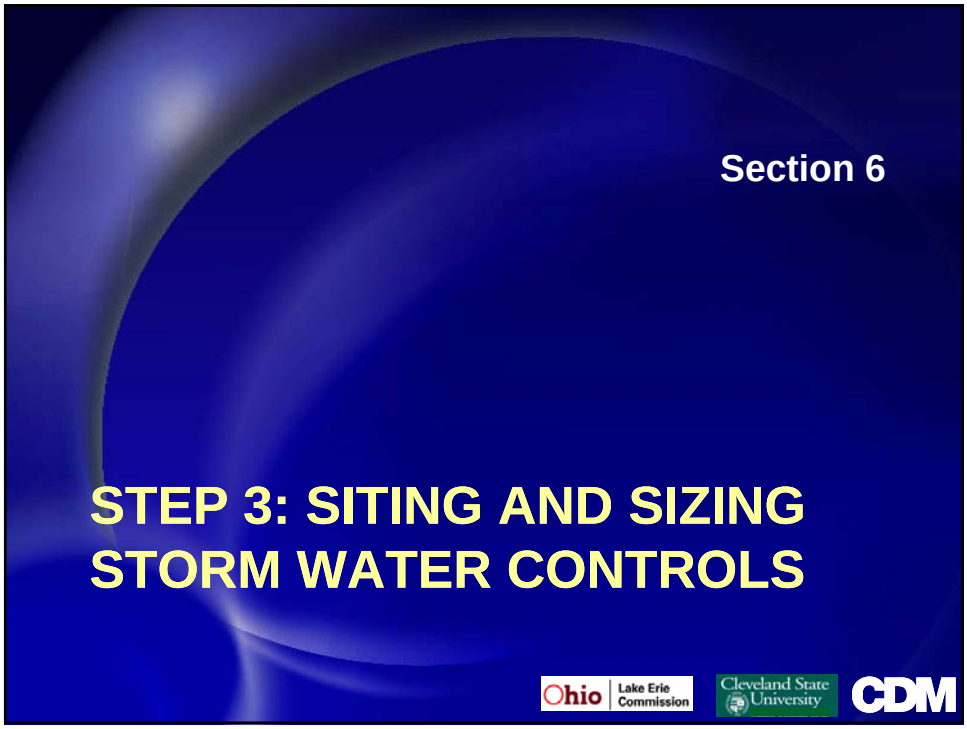
Section 6
STEP 3: SITING AND SIZING STORM WATER CONTROLS
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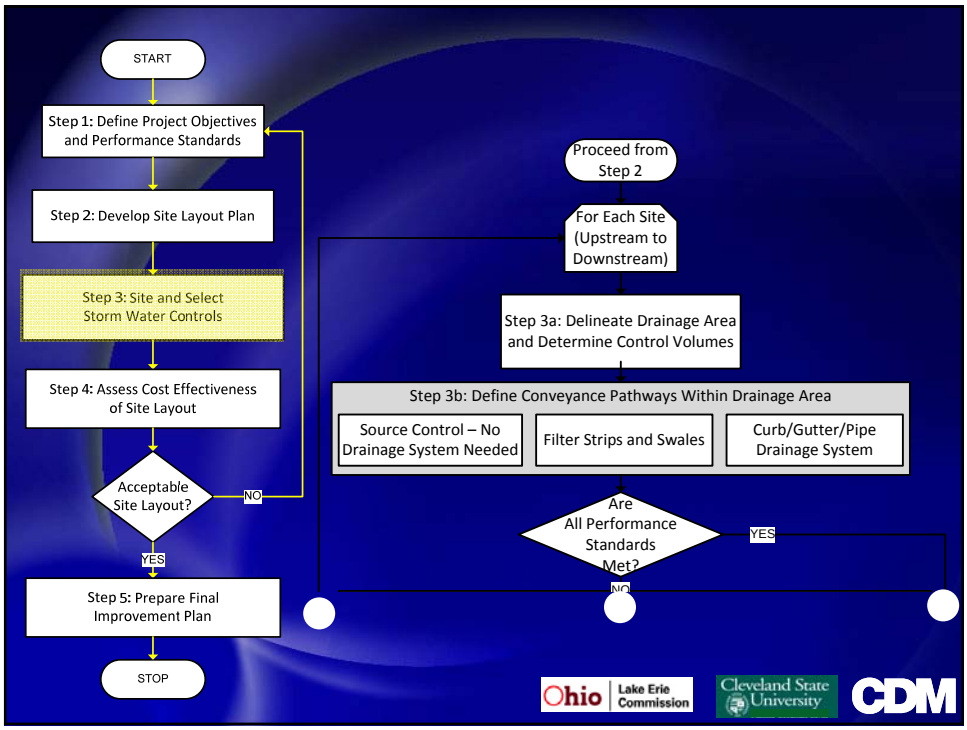
START
Step 1: Define Project Objectives and Performance Standards
Step 2: Develop Site Layout Plan
Step 3: Site and Select Storm Water Controls
Step 4: Assess Cost Effectiveness of Site Layout
Acceptable Site Layout?
NO
YES
Step 5: Prepare Final Improvement Plan
STOP
Proceed from Step 2
For Each Site (Upstream to Downstream)
Step 3a: Delineate Drainage Area and Determine Control Volumes
Step 3b: Define Conveyance Pathways Within Drainage Area
Source Control – No Drainage System Needed
Filter Strips and Swales
Curb/Gutter/Pipe Drainage System
Are All Performance Standards Met?
YES
NO
Ohio Lake Erie Commission
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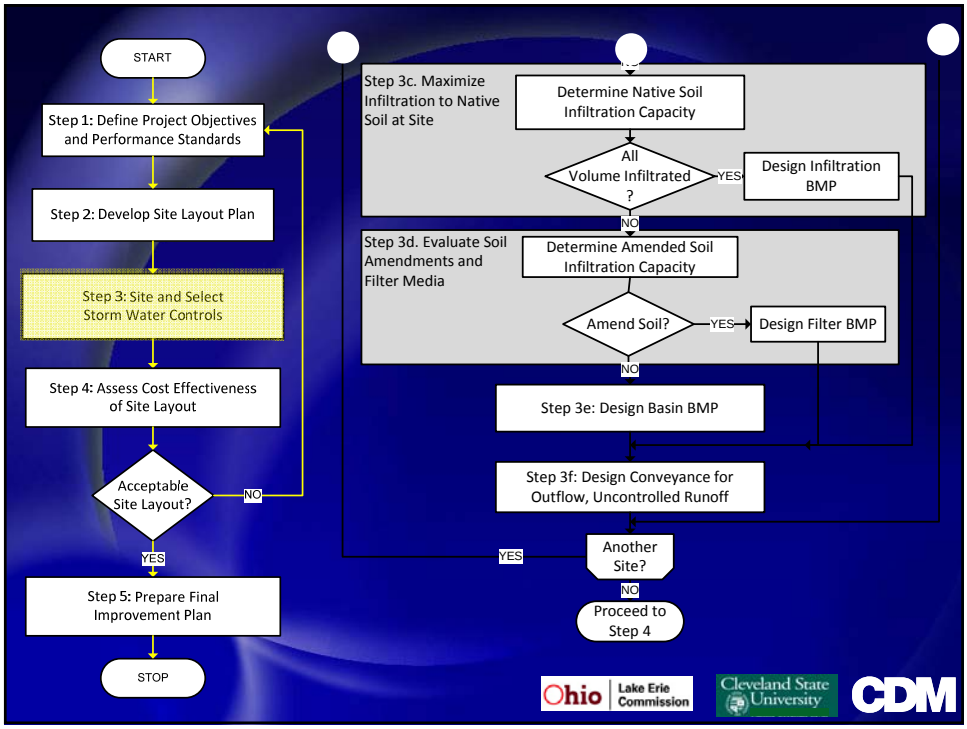
START
Step 1: Define Project Objectives and Performance Standards
Step 2: Develop Site Layout Plan
Step 3: Site and Select Storm Water Controls
Step 4: Assess Cost Effectiveness of Site Layout
Acceptable Site Layout?
NO
YES
Step 5: Prepare Final Improvement Plan
STOP
Step 3c. Maximize Infiltration to Native Soil at Site
Determine Native Soil Infiltration Capacity
All Volume Infiltrated ?
YES
Design Infiltration BMP
NO
Step 3d. Evaluate Soil Amendments and Filter Media
Determine Amended Soil Infiltration Capacity
Amend Soil?
YES
Design Filter BMP
NO
Step 3e: Design Basin BMP
Step 3f: Design Conveyance for Outflow, Uncontrolled Runoff
Another Site?
YES
NO
Proceed to Step 4
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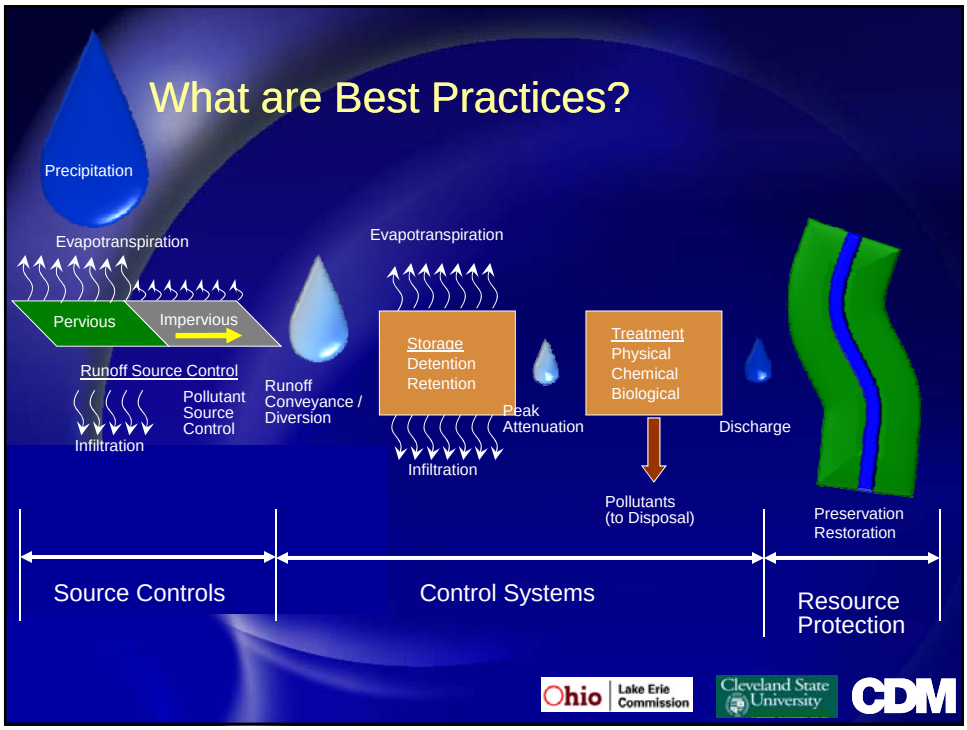
What are Best Practices?
Precipitation
Evapotranspiration
Pervious
Impervious
Runoff Source Control
Pollutant Source Control
Runoff Conveyance / Diversion
Infiltration
Evapotranspiration
Storage
Detention
Retention
Peak Attenuation
Infiltration
Treatment
Physical
Chemical
Biological
Discharge
Pollutants (to Disposal)
Preservation
Restoration
Source Controls
Control Systems
Resource Protection
Ohio Lake Erie Commission
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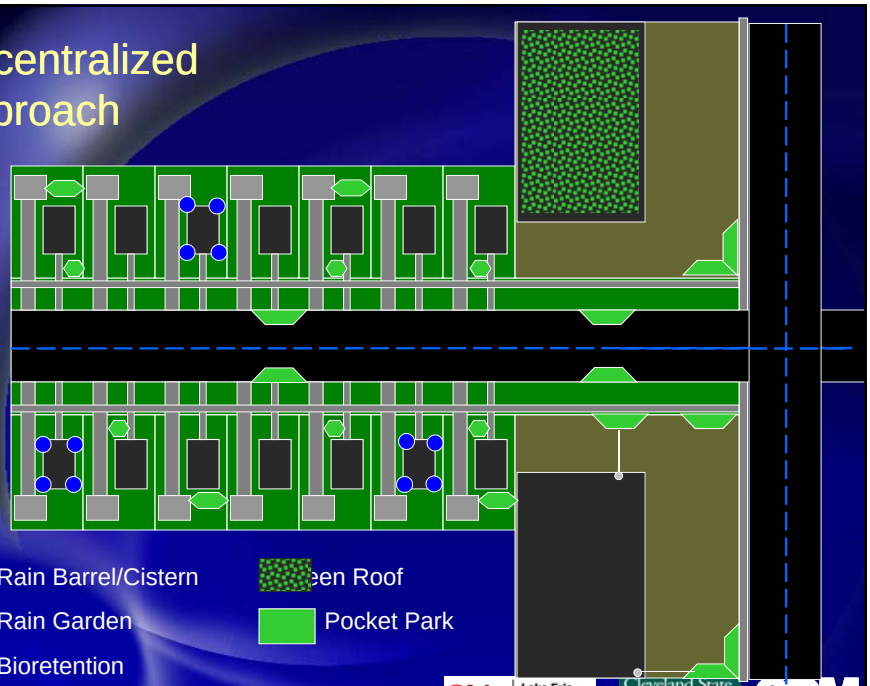
Best Local Land Use Practices to Illustrate through Case Studies

- Imperviousness control (e.g., reduce, disconnect, permeable materials)
- Vegetated filter strips and swales
- Infiltration practices (e.g., rain gardens, trenches, dry wells)
- Filters / underdrains (bioretention, soil amendments, sand, other)
- Basins (wet, dry, wetland, vaults)
- Stream, floodplain, and wetland enhancements / setbacks
- Integrated Combinations of Practices

Decentralized Approach



Opportunities and Barriers :
Less Imperviousness
Source Controls
Ohio Lake Erie Commission
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Opportunities and Barriers :
Permeable Pavements
Source Controls
Ohio Lake Erie Commission
Cleveland State University
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Opportunities and Barriers :
Disconnected Downspouts
Source Controls
Other Options to Handle Rooftop Runoff
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Opportunities and Barriers :
Rain Barrels and Cisterns
Source Controls
Downspout
First Flush Device
Master Tank
Secondary Tank
Pump
Drywell
(buried)
Outlet to Drywell
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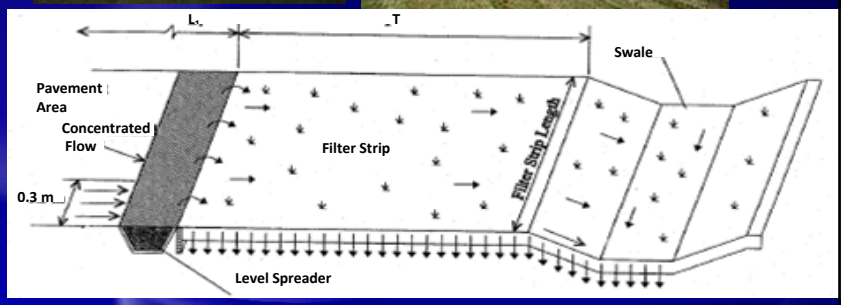
Conveyance / Treatment Systems for Yards / Roads / Parking

Opportunities and Barriers : Filter Strips and Swales



Control Systems for Yards

Opportunities and Barriers : Rain Gardens

Opportunities and Barriers :
Pocket Wetlands
Control Systems for Yards
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Opportunities and Barriers :
Bioretention
Control Systems for Roads / Parking
Not so good
drain
Good – Run-off from the parking lot can be absorbed by the plants and soil
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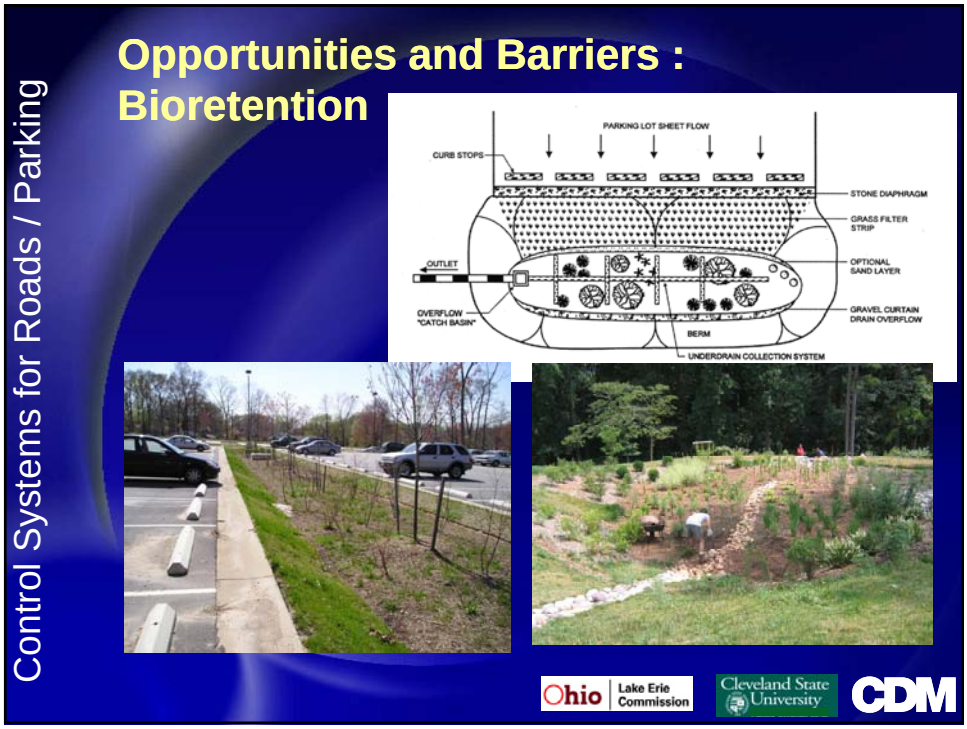
Control Systems for Roads / Parking
Opportunities and Barriers :
Bioretention
PARKING LOT SHEET FLOW
CURB STOPS
STONE DIAPHRAGM
GRASS FILTER STRIP
OPTIONAL SAND LAYER
OUTLET
OVERFLOW "CATCH BASIN"
GRAVEL CURTAIN DRAIN OVERFLOW
BERM
UNDERDRAIN COLLECTION SYSTEM
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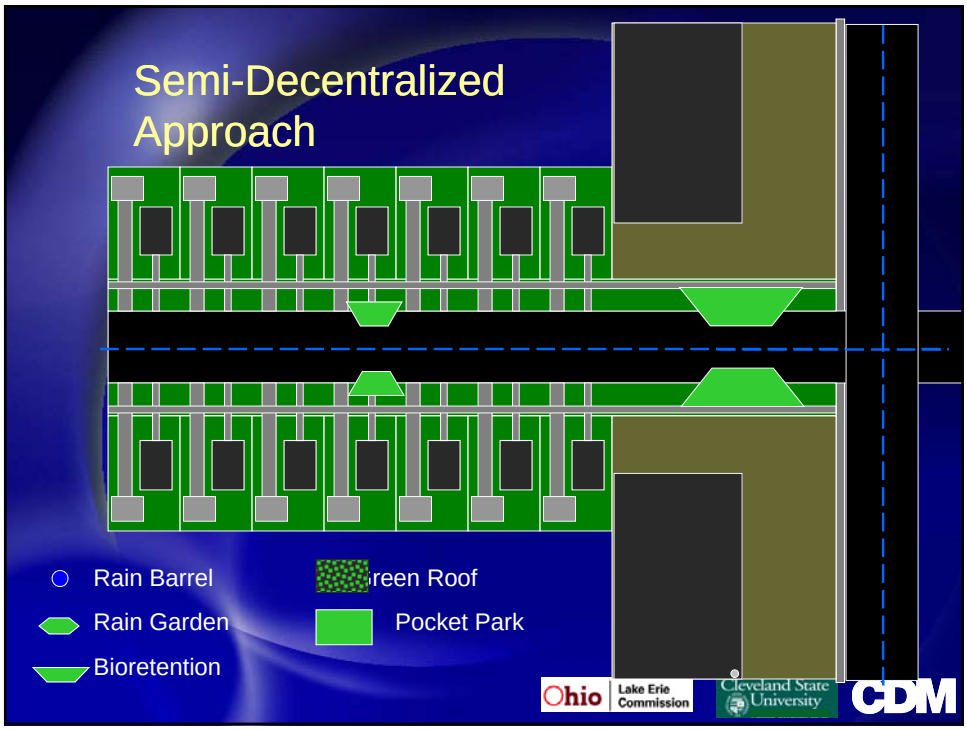
Semi-Decentralized
Approach
Rain Barrel
Green Roof
Rain Garden
Pocket Park
Bioretention
Ohio Lake Erie Commission
Cleveland State University
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Control Systems for Roads / Parking
Opportunities and Barriers : Bioretention
Before
After
After
Ohio Lake Erie Commission
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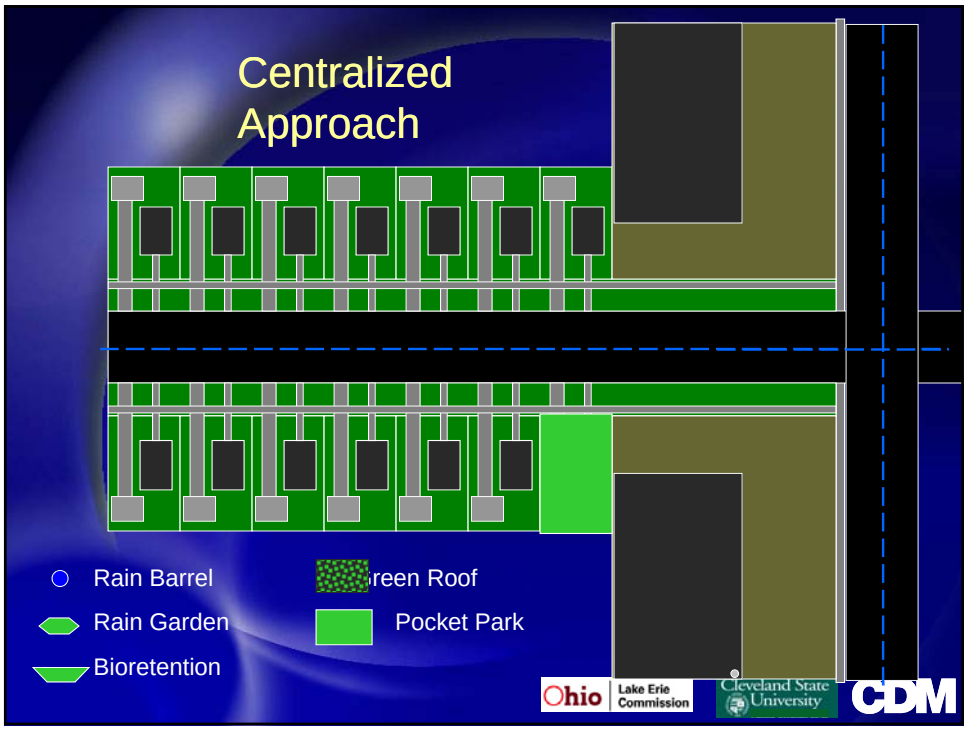
Centralized Approach
Rain Barrel
Rain Garden
Bioretention
reen Roof
Pocket Park
Ohio Lake Erie Commission
Cleveland State University
CDM

Control Systems for Sites/Regions

Opportunities and Barriers : Pocket Park with Best Practices

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Control Systems for Sites/Regions

Opportunities and Barriers : Basins for Water Quality / Quantity Control

Dry Extended Detention Basin

Wet Pond - Solids Settling

Wet Pond - Eutrophication

Wetland

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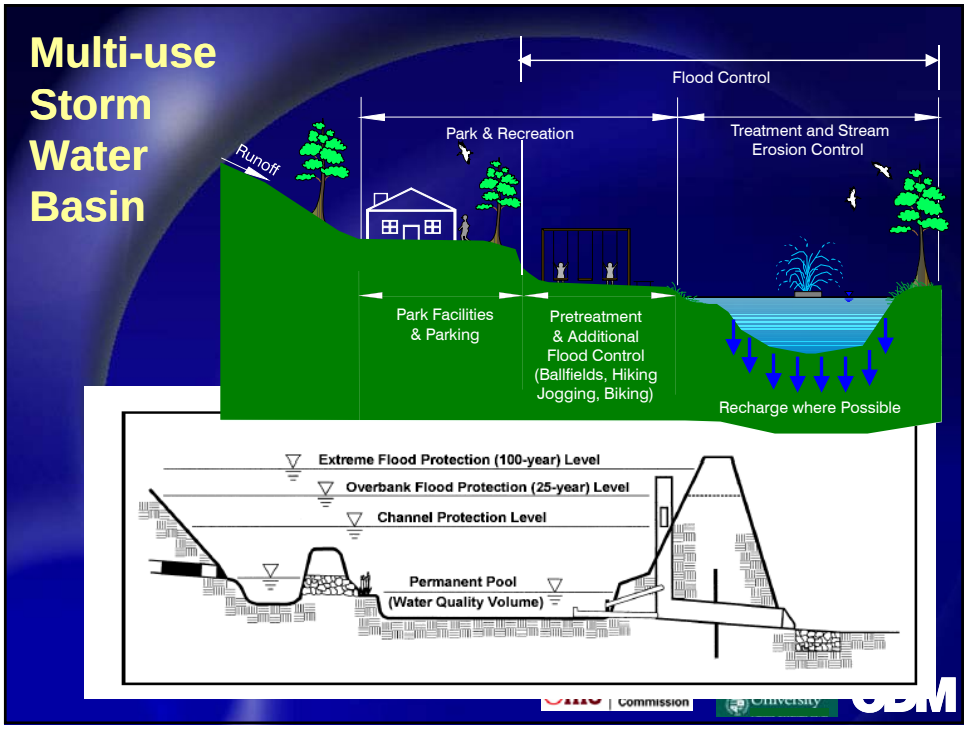
Multi-use Storm Water Basin
Flood Control
Park & Recreation
Treatment and Stream Erosion Control
Runoff
Park Facilities & Parking
Pretreatment & Additional Flood Control (Ballfields, Hiking Jogging, Biking)
Recharge where Possible
Extreme Flood Protection (100-year) Level
Overbank Flood Protection (25-year) Level
Channel Protection Level
Permanent Pool (Water Quality Volume)
CDM

Control Systems for Sites/Regions
Opportunities and Barriers :
Integrated Water Quality / Quantity Control
Bruns Ave. Elementary School Wetland and BMP Demonstration Project; Charlotte, NC
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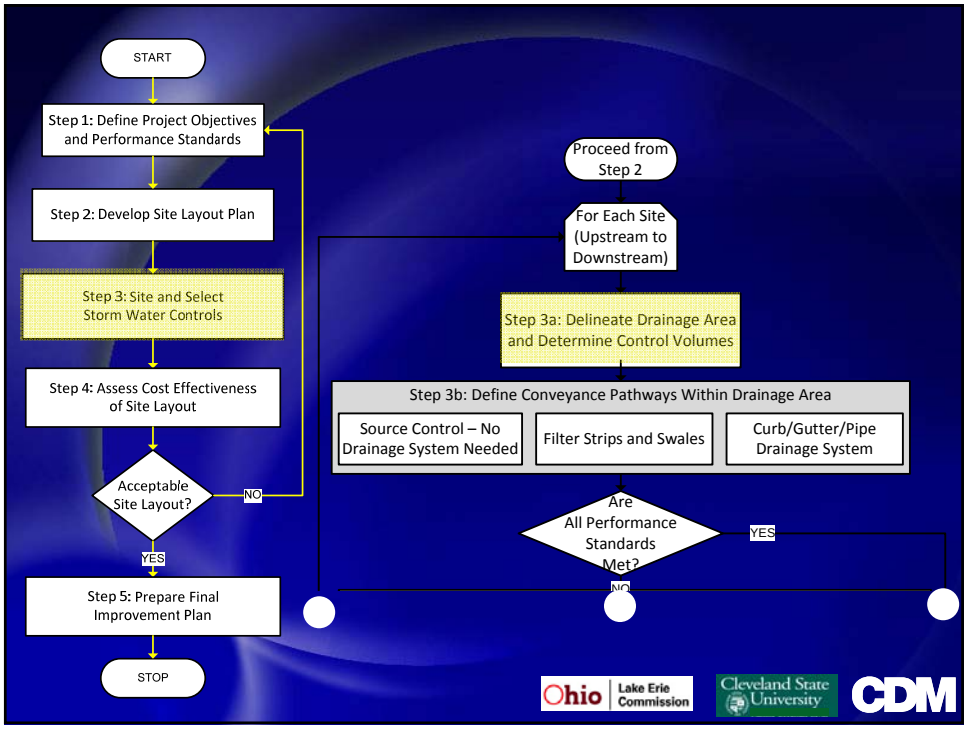


Step 3.a.1: Area Information

Step 3a Worksheet

Delineate Drainage Areas and Determine Control Volumes

Name: _____

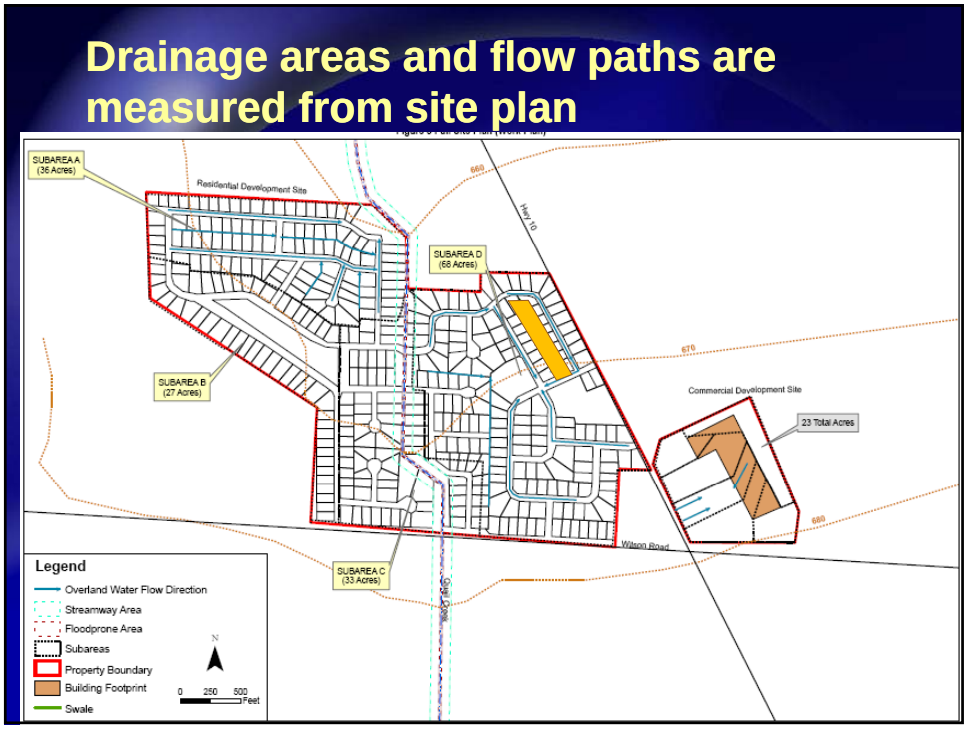
Site: _____

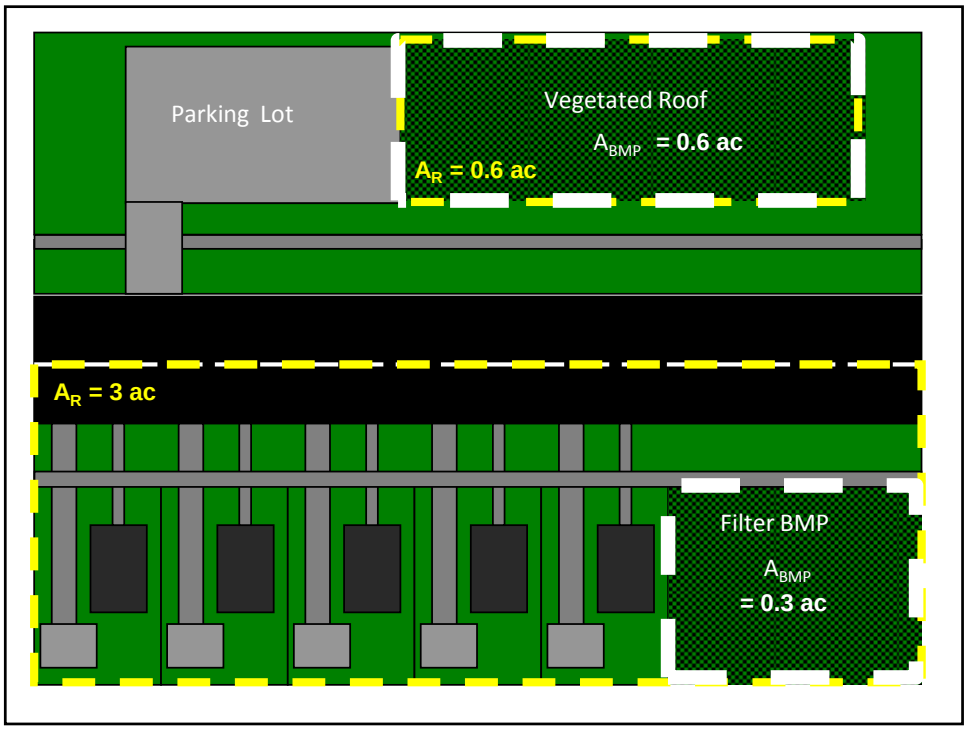
Date: _____

Use this worksheet to determine control volumes for best land use practice storm water BMPs. Complete one worksheet for the BMP site and each conveyance pathway (see Step 3b).

Step 3.a.1. Summarize BMP / conveyance pathway site characteristics.

Characteristic	Source
Catchment Area (A_R), acres = _____	*Project Site Plan (include area of BMP within catchment area)*
Available Surface Area (A_{BMP}), acres=_____	*Project Site Plan*
Tributary Area (A_T), acres=_____	$A_T = A_R - A_{BMP}$
Time of Concentration (T_c), minutes = _____	*Standard Hydrologic Calculation*


Drainage areas and flow paths are measured from site plan
SUBAREA A (36 Acres)
Residential Development Site
SUBAREA D (66 Acres)
SUBAREA B (27 Acres)
Commercial Development Site
23 Total Acres
SUBAREA C (33 Acres)
Legend
Overland Water Flow Direction
Streamway Area
Floodprone Area
Subareas
Property Boundary
Building Footprint
Swale
0 250 500 Feet


Parking Lot
Vegetated Roof
A_{BMP} = 0.6 ac
A_R = 0.6 ac
A_R = 3 ac
Filter BMP
A_{BMP}
= 0.3 ac

Step 3.a.1: Area Information

Step 3a Worksheet

Delineate Drainage Areas and Determine Control Volumes

Name: _____

Site: _____

Date: _____

Use this worksheet to determine control volumes for best land use practice storm water BMPs. Complete one worksheet for the BMP site and each conveyance pathway (see Step 3b).

Step 3.a.1. Summarize BMP / conveyance pathway site characteristics.

Characteristic	Source
Catchment Area (A_R), acres = 2.3 ac	*Project Site Plan (include area of BMP within catchment area)*
Available Surface Area (A_{BMP}), acres= 0.5 ac	*Project Site Plan*
Tributary Area (A_T), acres= 1.8 ac	$A_T = A_R - A_{BMP}$
Time of Concentration (T_c), minutes = 10 min	*Standard Hydrologic Calculation*

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Step 3.a.1 (cont.): Characteristics of Soils at BMP Site

Characteristics of Soil at BMP / conveyance pathway Site (From Table 3.a.1)

Soil Characteristic	Native Soil Infiltration (NI)	Enhanced Soil Infiltration – Filter/Planting Media (EI)	Source
Soil Texture Class			Table 3.a.1 or field data
Saturated Hydraulic Conductivity (K_{sat}), in/hr	$K_{sat\text{-}NI}$ =___	$K_{sat\text{-}EI}$ =___	
Porosity (P), fraction	P_{NI} =___	P_{EI} =___	
Field Capacity (FC), fraction	FC_{NI} =___	FC_{EI} =___	
Wilting Point (WP), fraction	WP_{NI} =___	WP_{EI} =___	
Depth of Soil (D), feet	D_{GW} =___	D_M =___	• D_{GW} = depth to restrictive layer • D_M depth of amended filter / planting bed
Depth of Water in Soil at:			
- Porosity (V_P), feet	$V_{P\text{-}NI}$ =___	$V_{P\text{-}EI}$ =___	*P * D*
- Field Capacity (V_{FC}), feet	$V_{FC\text{-}NI}$ =___	V_{FC_EI} =___	*FC * D*
- Wilting Point (V_{WP}), feet	$V_{WP\text{-}NI}$ =___	$V_{WP\text{-}EI}$ =___	*WP * D*

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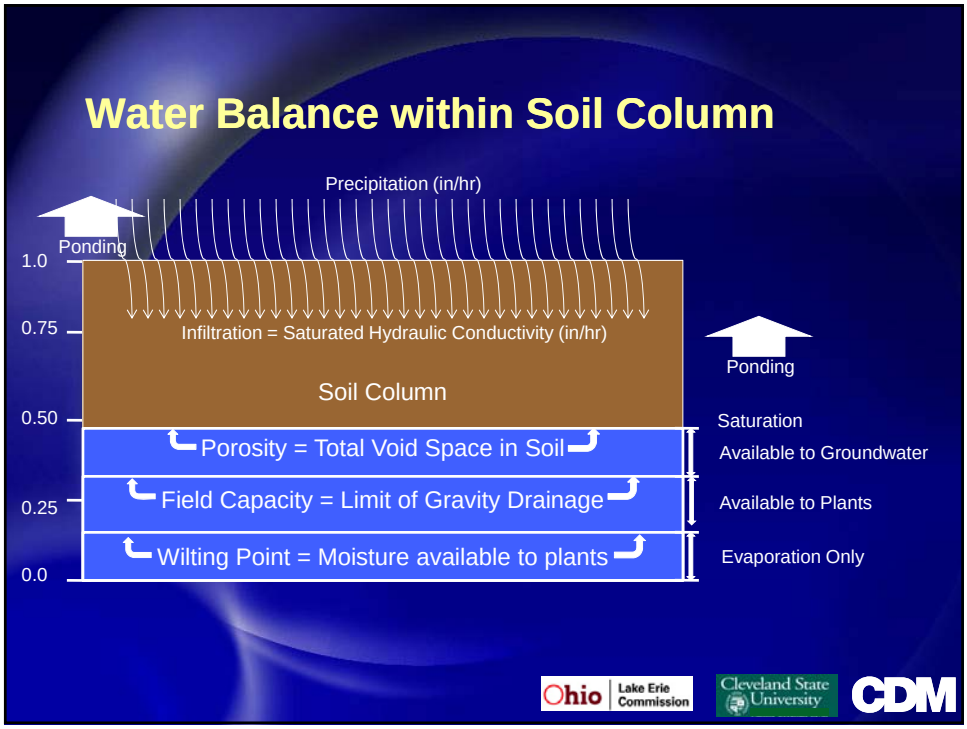
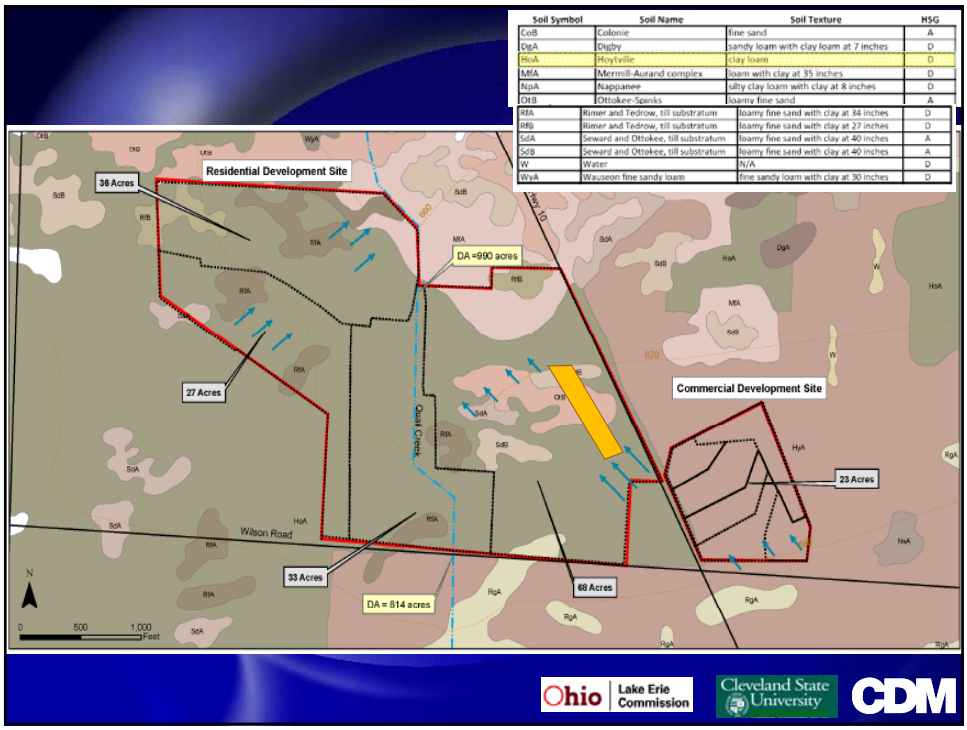




Soil Symbol	Soil Name	Soil Texture	HSG
CoB	Colonie	fine sand	A
DgA	Digby	sandy loam with clay loam at 7 inches	D
HoA	Hoytville	clay loam	D
MfA	Mermill-Aurand complex	loam with clay at 35 inches	D
NpA	Napoanee	silty clay loam with clay at 8 inches	D
OtB	Ottokee-Spinks	loamy fine sand	A
RfA	Rimer and Tedrow, till substratum	loamy fine sand with clay at 34 inches	D
RfB	Rimer and Tedrow, till substratum	loamy fine sand with clay at 27 inches	D
SdA	Seward and Ottokee, till substratum	loamy fine sand with clay at 40 inches	A
SdB	Seward and Ottokee, till substratum	loamy fine sand with clay at 40 inches	A
W	Water	N/A	D
WyA	Wauseon fine sandy loam	fine sandy loam with clay at 30 inches	D

Table 3.a.1. Infiltration Properties of Typical Soil Types

Table 3.a.1 – Infiltration Properties of Typical Soil Types

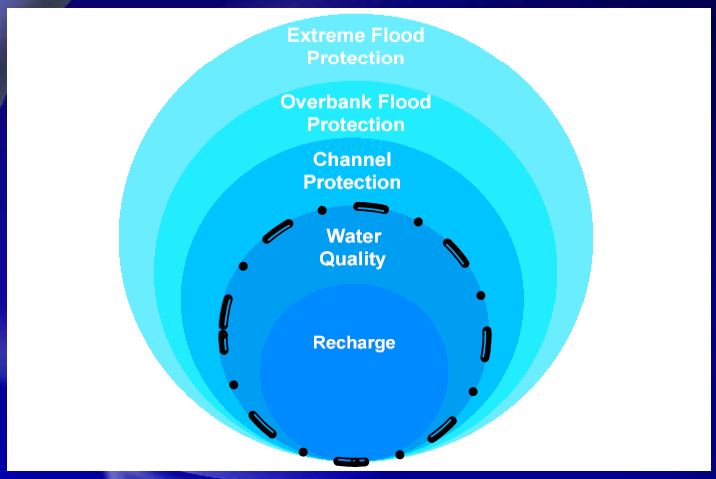
Soil Texture Class	Saturated Hydraulic Conductivity (K_{sat}), in/hr	Suction Head (S), inch	Porosity (P), fraction	Field Capacity (FC), fraction	Wilting Point (WP), fraction
Sand	4.74	1.93	0.437	0.062	0.024
Loamy Sand	1.18	2.40	0.437	0.105	0.047
Sandy Loam	0.43	4.22	0.453	0.190	0.085
Loam	0.13	3.50	0.463	0.232	0.116
Silt Loam	0.26	6.69	0.501	0.284	0.135
Sandy Clay Loam	0.06	8.66	0.398	0.244	0.136
Clay Loam	0.04	8.27	0.464	0.310	0.187
Silty Clay Loam	0.04	10.63	0.471	0.342	0.210
Sandy Clay	0.02	9.45	0.430	0.321	0.221
Silty Clay	0.02	11.42	0.479	0.371	0.251
Clay	0.01	12.6	0.475	0.378	0.265

Step 3.a.1 (cont.): Characteristics of Soils at BMP Site

Characteristics of Soil at BMP / conveyance pathway Site (From Table 3.a.1)

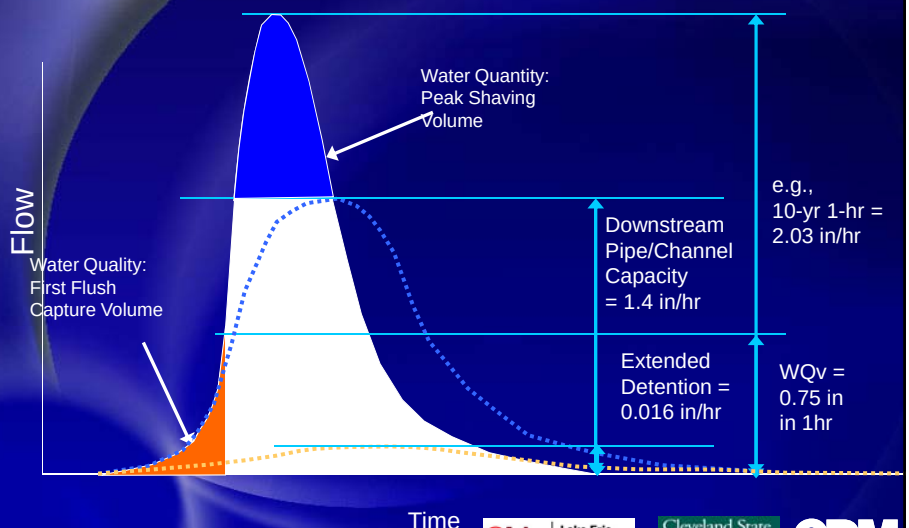
Soil Characteristic	Native Soil Infiltration (NI)	Enhanced Soil Infiltration – Filter/Planting Media (EI)	Source
Soil Texture Class	Clay Loam		Table 3.a.1 or field data
Saturated Hydraulic Conductivity (K_{sat}), in/hr	0.04	$K_{sat\text{-}EI}$ =___	
Porosity (P), fraction	0.464	P_{EI} =___	
Field Capacity (FC), fraction	0.310	FC_{EI} =___	
Wilting Point (WP), fraction	0.187	WP_{EI} =___	
Depth of Soil (D), feet	5	D_M =___	• D_{GW} = depth to restrictive layer • D_M depth of amended filter / planting bed
Depth of Water in Soil at:			
- Porosity (V_P), feet	2.32	$V_{P\text{-}EI}$ =___	*P * D*
- Field Capacity (V_{FC}), feet	1.55	V_{FC_EI} =___	*FC * D*
- Wilting Point (V_{WP}), feet	0.935	$V_{WP\text{-}EI}$ =___	*WP * D*

Unified Stormwater Sizing Criteria (Minnesota, 2005)



Small storm and large storm control strategies differ

Note: 1 in/hr ~ 1 cfs/ac



Water Quality Volume

$$WQ_v = C * P * A / 12$$

where:

WQ_v = water quality volume in acre-feet
C = runoff coefficient appropriate for storms less than 1 inch
= $0.858i^3 - 0.78i^2 + 0.774i + 0.04$ or $0.9i + 0.05$
I = percent imperviousness
P = rainfall in inches = 0.75 inches
A = area draining into the facility in acres

Capture volume depends on local precipitation statistics

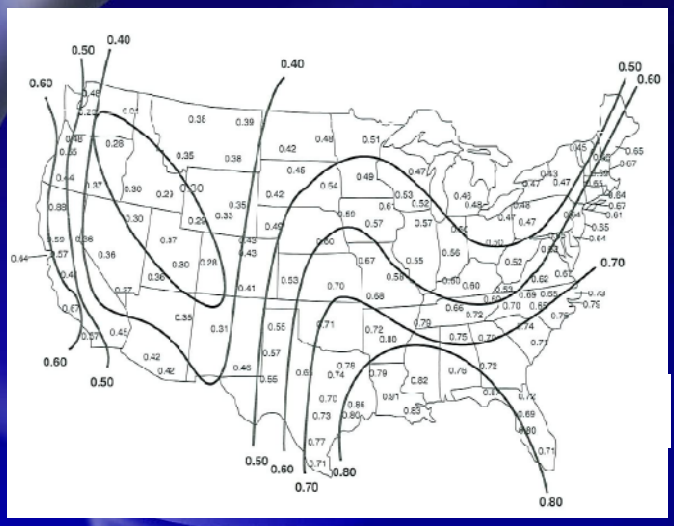


Figure 8. Mean storm precipitation depth in the U.S (inches) – Source: "Urban Runoff Quality Control", ASCE / WEF, 1997.

Capture volume depends on local precipitation statistics

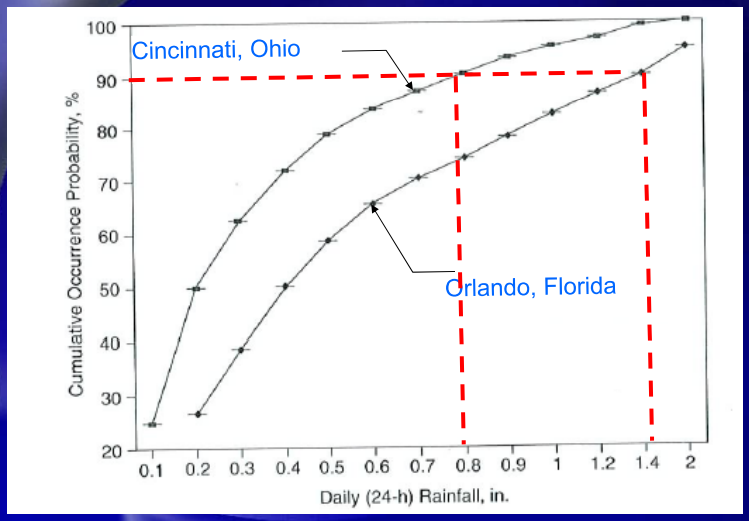
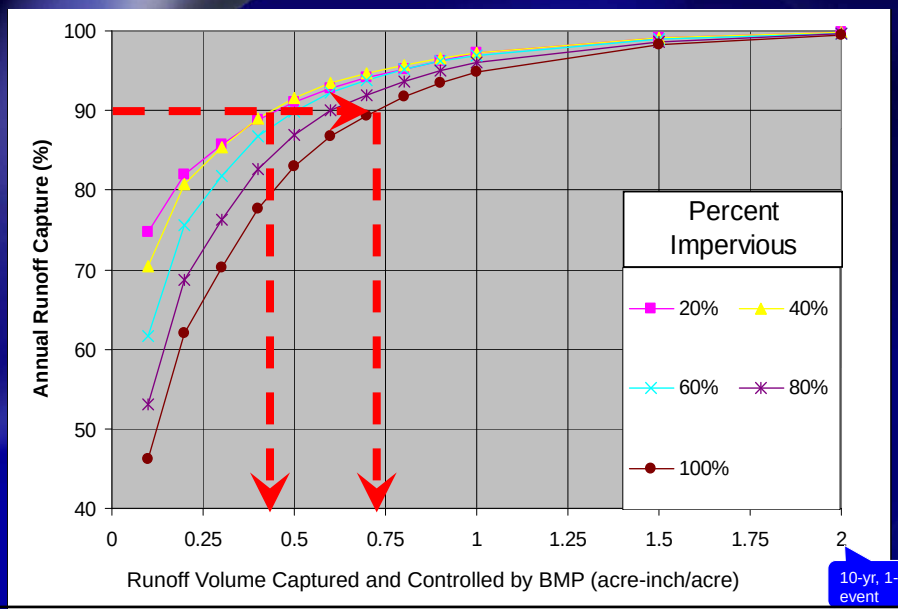


Figure 9. Cumulative probability distribution of daily precipitation for two cities in the U.S. (Roesner, et. al., 1991)

Capture volume depends on local precipitation statistics



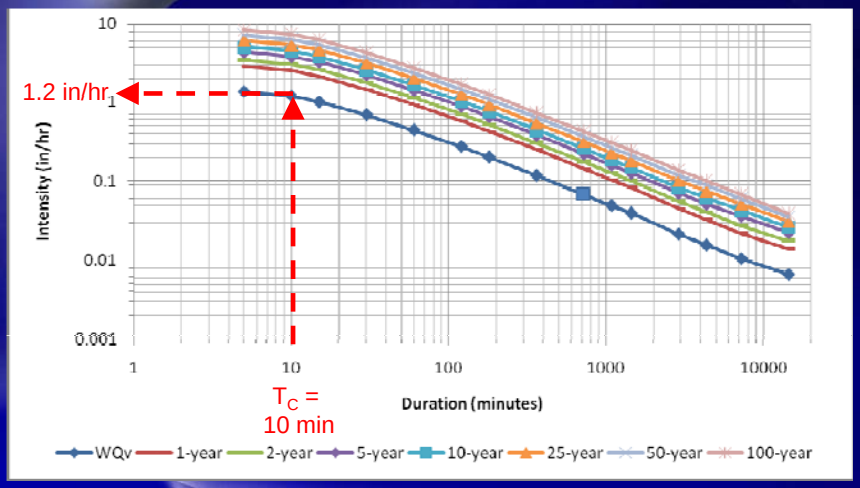
Step 3.a.2: Calculating Water Quality Volume

Characteristic	Source
Tributary Area Imperviousness (i_T), fraction = 0.4	*Post-construction land cover; i_T = a value between 0 and 1*
Tributary Area Water Quality Runoff Coefficient (C_T) = 0.28	$0.858*i_T^3 - 0.78*i_T^2 + 0.774*i_T + 0.04$
Catchment Water Quality Runoff Coefficient (C_{WQ}) = _____ = (0.5 ac * 1 + 1.8 ac * 0.28) / 2.3 ac = 0.44	$(A_{BMP} * 1 + A_T * C_T) / A_R$ *(Captures 100% of precipitation onto BMP, Swale, and Strip)*
Precipitation During Water Quality Event (P), feet = 0.0625	*0.75 inches (0.0625 ft) per Ohio EPA General Construction Permit*
WQv as depth , feet = 0.44 * 0.0625 ft = 0.028 ft	$= C_{WQ}*P$
WQv as volume, acre-feet = 0.028 ft * 2.3 ac = 0.064 ac-ft	$= C_{WQ}*P*A_R$

Step 3.a.3: Determine the Peak Flow Rate for the Water Quality Storm (Q_{WQ})

Characteristic	Source
Time of Concentration (T_C), minutes = _____	*Step 3.a.1*
Peak Intensity Rainfall, in/hr (I) = _____	*Interpolate from intensity-duration-frequency curves (see Figure 3.a.1 for Ohio Lake Erie region)*
Q_{WQ}, cfs = _____	$Q_{WQ} = C_{WQ}*I*A_R$

Figure 3.a.**1** – Intensity-Duration-Frequency Curves for the Ohio Lake Erie Region (Section 02)



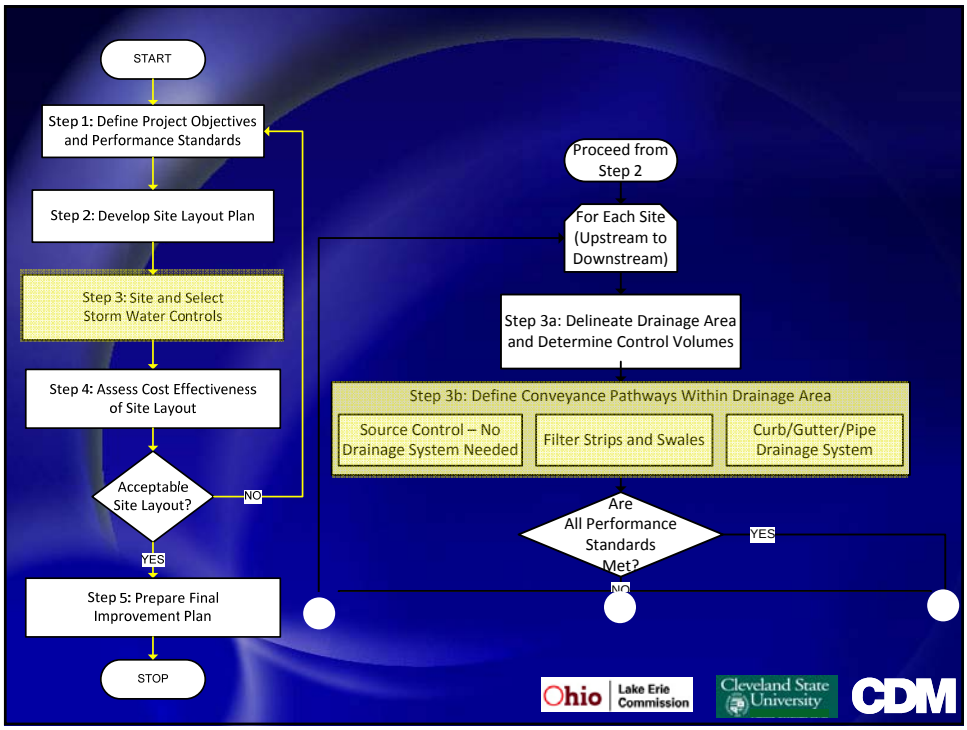
Adapted from Huff and Angel, 1992

Step 3.a.3: Determine the Peak Flow Rate for the Water Quality Storm (Q_{WQ})

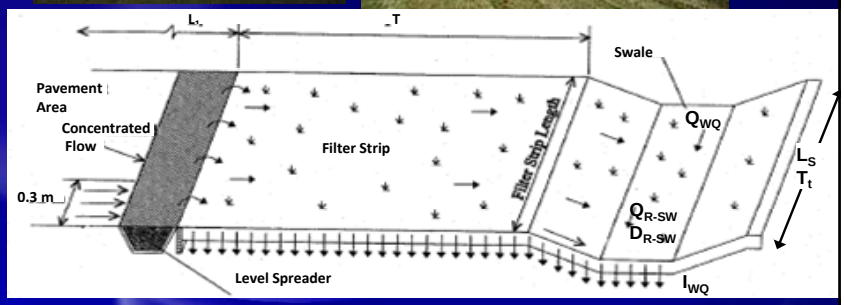
Characteristic	Source
Time of Concentration (T_C), minutes = 10 min	*Step 3.a.1*
Peak Intensity Rainfall, in/hr (I) = 1.2 in/hr	*Interpolate from intensity-duration-frequency curves (see Figure 3.a.1 for Ohio Lake Erie region)*
Q_{WQ}, cfs = 0.44 * 1.2 in/hr * 2.3 ac = 1.21 cfs	$Q_{WQ} = C_{WQ} * I * A_R$

STEP 3.a.4. Determine Initial Soil Moisture Conditions

Characteristic	Source
Allowable period of surface ponding, days = 2 days	*Typically 2-3 days*
Antecedent Soil Moisture at Start of Water Quality Event (V_{AM}), feet = 1.55 ft	$V_{FC\text{-}NI}$ or V_{FC_EI} *(see Step 3.a.1)*



Filter Strips and Swales



Backyard swales are common within many developments

Step 3.b.1: Swale Design Parameters

Characteristic	Source
Area Tributary to conveyance pathway (A_T), acres=_____	*Step 3.a.1*
Tributary Area Imperviousness (i_T), fraction = _____	*Step 3.a.1*
Catchment slope (S_C) , ft/ft = _____	*Measure from proposed site topography*
Time of Concentration (T_c), minutes = _____	*Step 3.a.1*
Saturated hydraulic conductivity of native soil underlying conveyance pathway (K_{sat-NI}), in/hr = _____	*Step 3.a.1*
Porosity of native soil underlying conveyance pathway (V_{P-NI}), feet = _____	*Step 3.a.1*
Field capacity of native soil underlying conveyance pathway (V_{FC-NI}), feet = _____	*Step 3.a.1*
Slope of conveyance pathway (S_S), ft/ft = _____	*Measure from proposed site topography*
Available length of conveyance pathway (L_S), ft = _____	*Measure from proposed site plan*
Available width of conveyance pathway (TW), ft = _____	*Measure from proposed site plan*
Water Quality Volume entering conveyance pathway, as depth (WQv), feet = _____	*Step 3.a.2*
Peak Flow Rate of Water Quality Storm (Q_{WQ}), cfs = _____	*Step 3.a.3*

STEP 3.b.2: Evaluate Site Conditions to Determine if a Grass Filter Strip is a Feasible BMP Option.

Answer yes or no to each of the questions below.

_____ Will runoff enter the filter strip area as sheet flow?

_____ Is the slope of the filter strip area between 1 and 5 percent? (Calculated slope is ____ %)

_____ Do soil conditions allow for diffuse vegetative cover to become established?

_____ Is the drainage area to the filter strip site less than 5 acres?

_____ Is a minimum filter strip length of 25 feet?

_____ Is the flow path through the filter strip area limited to 150 feet if completely vegetated or 75 feet if the area tributary to the filter strip area is impervious?

If you answered no to any of the questions above, a filter strip may not be feasible at the BMP site you are evaluating. Proceed to Step 3.b.3. to evaluate the feasibility of a vegetated swale conveyance system. If all questions were answered YES, then evaluate the infiltration with the filter strip area using Step 3.b.3 and a wide channel assumption for the swale bottom width.

Step 3.b.3: Sizing for Water Quality ($Q_{WQ} = [1.486* A*R^{2/3}*S_S^{1/2}] / n$)

Characteristic	Source
Height of vegetation in swale, feet = _____	*Recommend mowing to height of 3 to 6 inches (0.25 to 0.5 ft)*
Mannings n (n_S) = _____	*Ranges between 0.2 and 0.3 if peak flow depth during Q_{WQ} is less than 50% of vegetation height within the swale*
Slope of swale (S_S), ft/ft = _____	*Range of 0.0005 to 0.05 ft/ft (0.5 to 5 percent) recommended*
$A*R^{2/3}$ = _____	*= $[Q_{WQ} *n_S]/ [1.486*S_S^{1/2}]$*
Maximum flow depth (d_{WQ}), ft = _____	*< 50% of mowed vegetation height*
Bottom width (w_S), ft = _____	*Use Table 3.b.1 , the calculated $A*R^{2/3}$, and the maximum flow depth (d_{WQ}). Typically between 2 to 8 ft*
Length of swale (L_S), ft = _____	*Proposed site plan, minimum of 100 ft*
Side slope (H:1) = _____	*Usually milder than 3:1*

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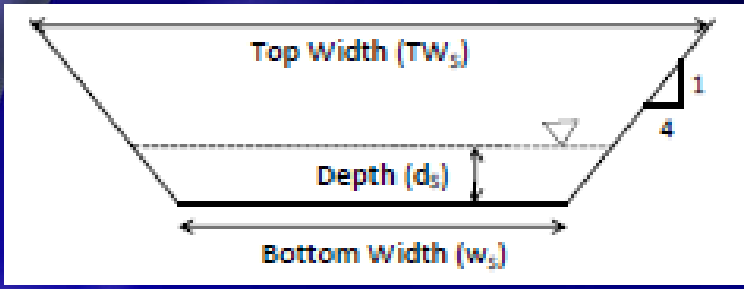
Step 3.b.4: Calculate the Swale Cross-Sectional Area at peak Q_{WQ}



Characteristic	Source
Area (A_{WQ}), ft^2 = _____	$A_{WQ} = (w_S+4d_{WQ})*d_{WQ}$

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Look-up table for $AR^{2/3}$

Width (ft)

Depth (ft)	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0
0.25	0.632	0.652	0.671	0.691	0.711	0.730	0.750	0.770	0.790	0.809	0.829
0.26	0.669	0.690	0.711	0.731	0.752	0.773	0.794	0.815	0.835	0.856	0.877
0.27	0.707	0.729	0.751	0.773	0.795	0.816	0.838	0.860	0.882	0.904	0.926
0.28	0.746	0.769	0.792	0.815	0.838	0.861	0.884	0.907	0.930	0.953	0.976
0.28	0.786	0.810	0.834	0.858	0.883	0.907	0.931	0.955	0.979	1.004	1.028
0.29	0.827	0.852	0.877	0.903	0.928	0.953	0.979	1.004	1.030	1.055	1.081
0.30	0.868	0.895	0.921	0.948	0.975	1.001	1.028	1.054	1.081	1.108	1.134
0.31	0.911	0.939	0.967	0.994	1.022	1.050	1.078	1.106	1.134	1.162	1.189
0.32	0.955	0.984	1.013	1.042	1.071	1.100	1.129	1.158	1.187	1.216	1.246
0.33	0.999	1.030	1.060	1.090	1.120	1.151	1.181	1.212	1.242	1.272	1.303
0.33	1.045	1.076	1.108	1.140	1.171	1.203	1.234	1.266	1.298	1.330	1.361
0.34	1.091	1.124	1.157	1.190	1.223	1.256	1.289	1.322	1.355	1.388	1.421
0.35	1.139	1.173	1.207	1.241	1.276	1.310	1.344	1.379	1.413	1.447	1.482
0.36	1.187	1.222	1.258	1.294	1.329	1.365	1.401	1.436	1.472	1.508	1.544
0.37	1.236	1.273	1.310	1.347	1.384	1.421	1.458	1.495	1.532	1.569	1.607
0.38	1.286	1.325	1.363	1.401	1.440	1.478	1.517	1.555	1.594	1.632	1.671
0.38	1.338	1.377	1.417	1.457	1.497	1.537	1.576	1.616	1.656	1.696	1.736
0.39	1.390	1.431	1.472	1.513	1.554	1.596	1.637	1.678	1.720	1.761	1.803
0.40	1.443	1.485	1.528	1.571	1.613	1.656	1.699	1.742	1.784	1.827	1.870
0.41	1.497	1.541	1.585	1.629	1.673	1.717	1.762	1.806	1.850	1.895	1.939
0.42	1.552	1.597	1.643	1.688	1.734	1.780	1.826	1.871	1.917	1.963	2.009
0.43	1.608	1.655	1.702	1.749	1.796	1.843	1.891	1.938	1.985	2.032	2.080
0.43	1.664	1.713	1.762	1.810	1.859	1.908	1.957	2.005	2.054	2.103	2.152
0.44	1.722	1.772	1.823	1.873	1.923	1.973	2.024	2.074	2.124	2.175	2.225
0.45	1.781	1.833	1.884	1.936	1.988	2.040	2.092	2.144	2.196	2.248	2.300
0.46	1.841	1.894	1.947	2.001	2.054	2.108	2.161	2.215	2.268	2.322	2.375

Step 3.b.5&6: Calculate Flow, Travel Time in Swale

Characteristic	Source
Velocity (v_{WQ}) , ft/sec = _____	*= Q_{WQ} / A_{WQ}; Maximum 0.9 ft/sec. If velocity is greater than 0.9 ft/sec, go back to site layout plan to flatten the longitudinal slope,, reduce tributary area to the swale, or use a conventional conveyance system.*

Characteristic	Source
Travel Time (T_t) , hr = _____	*= L_S / (v_{WQ} * 3600)*

Step 3.b.7: Check major storm capacity

Characteristic	Source
Peak 100-year flow (Q_{100}), cfs = _____	*Use standard hydrologic calculations*
Manning's n (n_{100}) = _____	*Ranges between 0.03 and 0.05 where peak flow depth during Q_{100} exceeds the height of vegetation.*
$A*R^{2/3}$ = _____	$= [Q_{100} * n_{100}] / [1.486 * S_S^{1/2}]$
Maximum flow depth (d_{100}), ft = _____	*Use Table 3.b.1, the calculated $A*R^{2/3}$, and the swale bottom width (w_S) determined in Step 3.b.3.*
TW_{100}, ft = _____	$= w_S + 8*d_{100}$
Check that TW_{100} is less than available top width of swale: YES NO	*If TW_{100} is greater than the width available for the BMP, go back to site layout plan to reduce tributary area to the swale, reduce impervious area, increase allowable area for the BMP or use a conventional conveyance system.*

Step 3.b.8: Adjust WQ_V for Infiltration within Swale

Characteristic	Source
Travel time through swale (T_t), hours = _____	*From Step 3.b.6*
Infiltration during the WQ event (V_{NI}), feet = _____ (Note: use WQv as depth from Step 3.a.2)	*= Minimum of:* • $K_{sat\text{-}NI} * T_t$ • $WQv\ (ft) * A_R / (w_S * L_S)$
Runoff depth from Swale (WQv_{ADJ}), feet = _____	$WQv - V_{NI}$

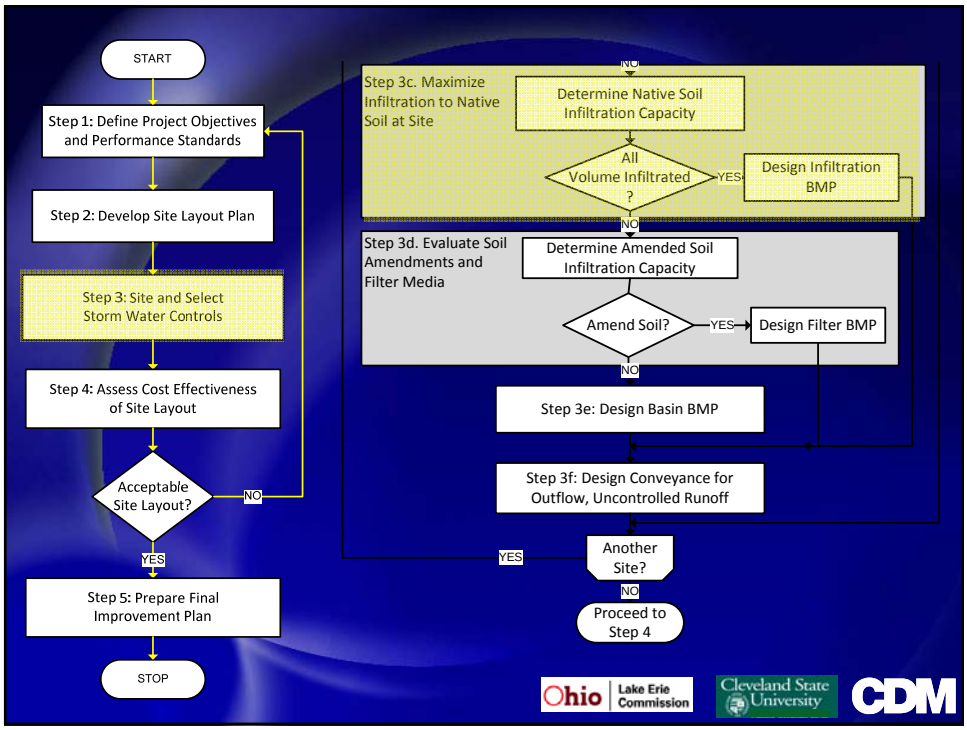
- *If adjusted WQv (WQv_{ADJ}) = 0, swale / filter strip meets all storm water management objectives for the site. If not, set WQv = WQv_{ADJ} and proceed to Step 3c.*
- *If multiple drainage paths exist within the catchment tributary to the BMP site, repeat Steps 3a and 3b for each path.*

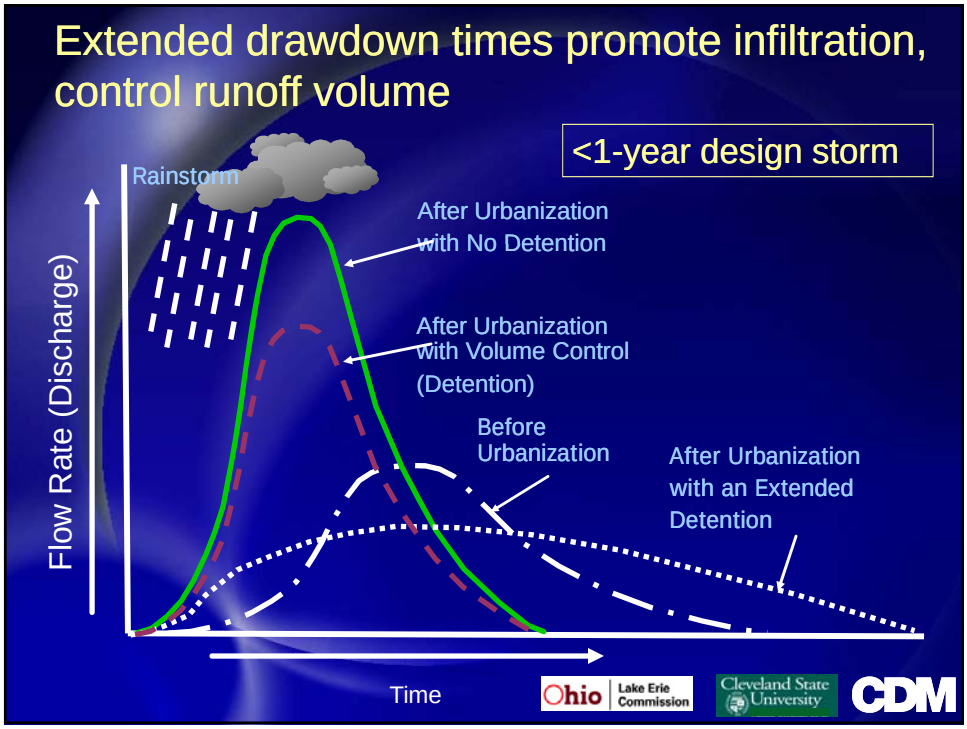
Group Discussion Topic #4a: Drainage Areas and Internal Drainage (Steps 3a & 3b)

Problem Statement #1

Using Worksheet 3.a, determine the control volumes for design of a swale drainage system within Sub-area D. Once complete, use Worksheet 3.b to size the swale accordingly based on the following parameters:

Swale drainage area (A_R)	*2.3 acres*
Impervious fraction (i_T)	*0.4*
Time of Concentration(T_c)	*10 minutes*
Available swale length x width (including easement)	*687 feet x 30 feet*
Allowable surface ponding time (t)	*2 days*
Slope of Swale (S_s)	*0.04 ft/ft*
Peak 100-year flow (Q_{100})	*4.5 cfs*




Extended drawdown times promote infiltration, control runoff volume
<1-year design storm
Rainstorm
Flow Rate (Discharge)
After Urbanization with No Detention
After Urbanization with Volume Control (Detention)
Before Urbanization
After Urbanization with an Extended Detention
Time
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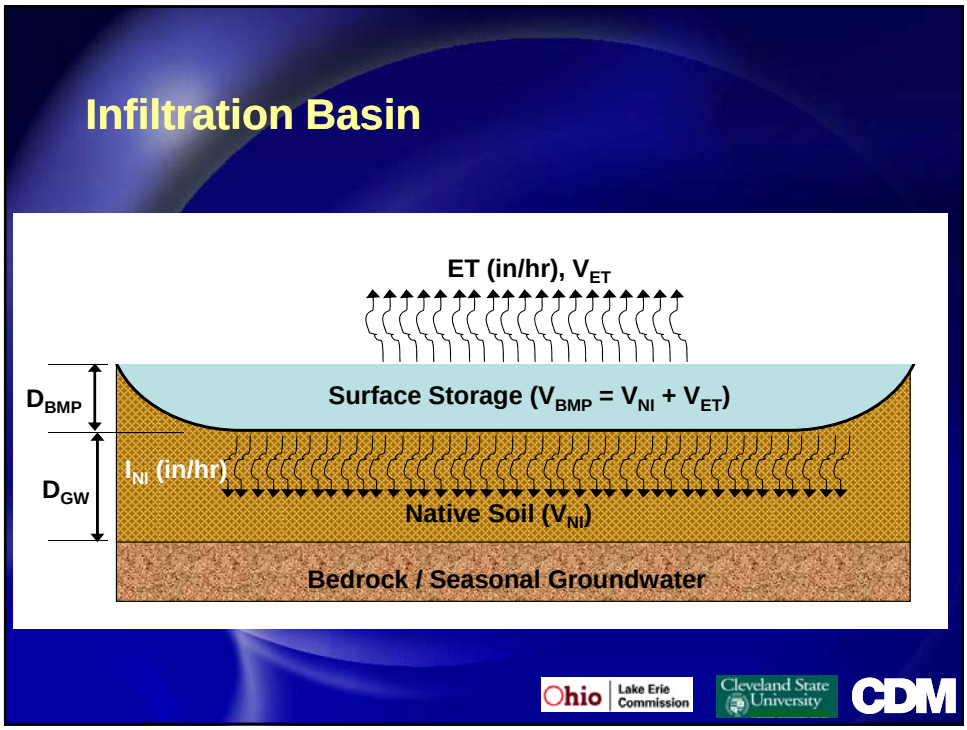
Infiltration Basin
ET (in/hr), V_{ET}
D_{BMP}
Surface Storage ($V_{BMP} = V_{NI} + V_{ET}$)
D_{GW}
I_{NI} (in/hr)
Native Soil (V_{NI})
Bedrock / Seasonal Groundwater
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Step 3.c.1: BMP Site 1 Characteristics

Characteristic	Source
Catchment Area (A_R), acres = _____	*Step 3.a.1*
Surface Area of BMP (A_{BMP}), acres=_____	*Step 3.a.1*
Area Tributary to BMP (A_T), acres=_____	*Step 3.a.1*

Step 3.c.2: Determine Total Water Quality Volume Entering BMP site

Conveyance Pathway ID	Runoff Area (A_R), acres	Water Quality Volume (WQv or WQv_{ADJ}),	
		Depth (feet), from Step 3.a.2	Volume (ac-ft) = A_R * WQv (ft)
BMP surface*			
Total	Σ A_R = ____	N/A	Σ WQv (by volume) = _____
WQv in BMP (D_{BMP}), by depth (ft) = Σ WQv (by volume) / Σ A_{BMP} = _____			

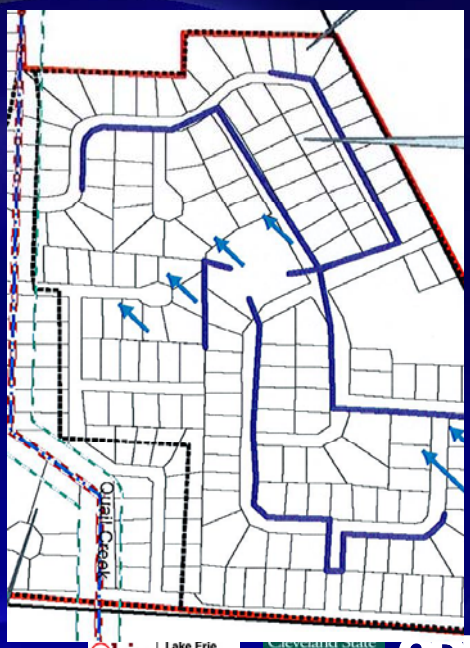
* Unless already included in the WQv calculation in Step 3.a.2

Step 3.c.3: Native Soil Infiltration within BMP (pass 1)

Characteristic	Source
Allowable surface ponding time (t), hours = _____	*Typically 24 to 48 hours*
Infiltration into Native Soil (V_{NI}), feet = _____	*Minimum of :* • $K_{sat\text{-}NI} * t$ • D_{BMP} *(from 3.c.2)*
Surface condition: Ponded Infiltrated	*If* $D_{BMP} > V_{NI}$, *surface ponding occurs* *If* $V_{NI} \geq D_{BMP}$ *then the water is infiltrated into the native soil.*
Surface detention volume (V_{SD}), feet = _____	$D_{BMP} - V_{NI}$

If the surface condition is infiltrated then infiltration into the native soil appears to be a feasible option for this BMP site. Site measured infiltration rates should be used during design and a monthly water budget should be performed to determine soil moisture conditions for plant survivability during wet and dry months. If surface condition is ponded, then a soil amendment (Step 3.d) can be considered or proceed directly to basin BMP design (Step 3.e.).

Group Discussion Topic #4b: Native Soil Infiltration Capacity (Step 3c)



Group Discussion Topic #4b: Native Soil Infiltration Capacity (Step 3c)

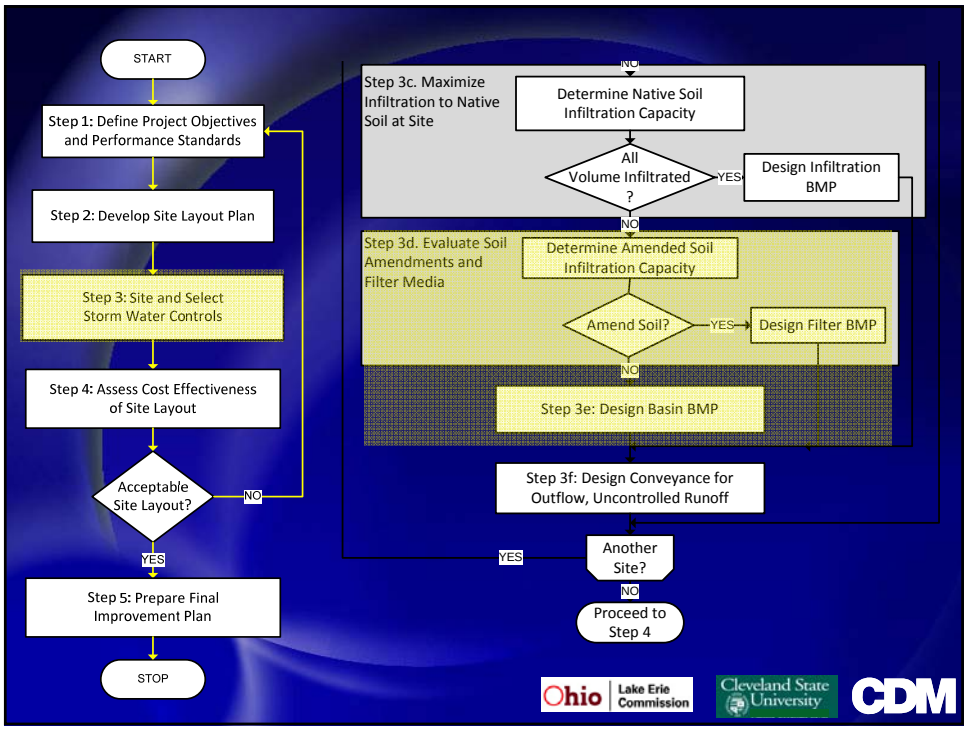
Problem Statement #2

Consider native soil properties within Sub-area D for ideal BMP locations. Using Worksheet 3.a, determine the control volumes for design of an infiltration/filter/basin BMP at locations ideal for this type of BMP. The swale designed in Problem Statement #1 should be included within this drainage area. Base your design upon the following parameters:

Catchment area (A_R)	*20.25 acres*
BMP surface area(A_{BMP})	*2.79 acres*
Impervious fraction (i_T)	*0.6*
Time of Concentration(T_c)	*20 minutes*

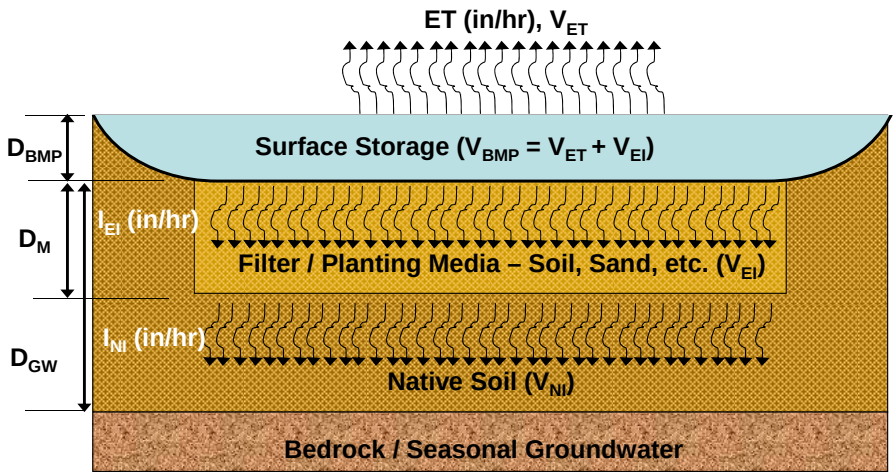
The next step will be to use Worksheets 3.c, 3.d, & 3.e to maximize native infiltration, evaluate soil amendments, and design a basin size for the control volumes calculated above and in Problem Statement #1. Worksheet 3.b is not used in this exercise because it is assumed that all drainage, other than that calculated in Problem Statement #1, is conveyed via conventional methods. Use the following parameters when completing the worksheets:

Allowable surface ponding time (t)	*24 hours*
Subsurface Dewatering Period (t_{DW})	*3 days*
Evapotranspiration rate (ET)	*0.11 in/day*
Time of Concentration(T_c)	*20 minutes*



Combination Filter / Infiltrator

Combination Filter / Infiltrator



Step 3.a.1: Characteristics of Soils at BMP Site

Characteristics of Soil at BMP / conveyance pathway Site (From Table 3.a.1)

Soil Characteristic	Native Soil Infiltration (NI)	Enhanced Soil Infiltration – Filter/Planting Media (EI)	Source
Soil Texture Class	Clay Loam		Table 3.a.1 or field data
Saturated Hydraulic Conductivity (K_{sat}), in/hr	0.04	$K_{sat\text{-}EI}$ =___	
Porosity (P), fraction	0.464	P_{EI} =___	
Field Capacity (FC), fraction	0.310	FC_{EI} =___	
Wilting Point (WP), fraction	0.187	WP_{EI} =___	
Depth of Soil (D), feet	5	D_M =___	• D_{GW} = depth to restrictive layer • D_M depth of amended filter / planting bed
Depth of Water in Soil at:			
- Porosity (V_P), feet	2.32	$V_{P\text{-}EI}$ =___	*P * D*
- Field Capacity (V_{FC}), feet	1.55	V_{FC_EI} =___	*FC * D*
- Wilting Point (V_{WP}), feet	0.935	$V_{WP\text{-}EI}$ =___	*WP * D*

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Table 3.a.1. Infiltration Properties of Typical Soil Types

Soil Texture Class	Saturated Hydraulic Conductivity (K_{sat}), in/hr	Suction Head (S), inch	Porosity (P), fraction	Field Capacity (FC), fraction	Wilting Point (WP), fraction
Sand	4.74	1.93	0.437	0.062	0.024
Loamy Sand	1.18	2.40	0.437	0.105	0.047
Sandy Loam	0.43	4.22	0.453	0.190	0.085
Loam	0.13	3.50	0.463	0.232	0.116
Silt Loam	0.26	6.69	0.501	0.284	0.135
Sandy Clay Loam	0.06	8.66	0.398	0.244	0.136
Clay Loam	0.04	8.27	0.464	0.310	0.187
Silty Clay Loam	0.04	10.63	0.471	0.342	0.210
Sandy Clay	0.02	9.45	0.430	0.321	0.221
Silty Clay	0.02	11.42	0.479	0.371	0.251
Clay	0.01	12.6	0.475	0.378	0.265

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Step 3.a.1: Characteristics of Soils at BMP Site - Enhanced Soil Infiltration

Characteristics of Soil at BMP / conveyance pathway Site (From Table 3.a.1)

Soil Characteristic	Native Soil Infiltration (NI)	Enhanced Soil Infiltration – Filter/Planting Media (EI)	Source
Soil Texture Class	Clay Loam	Sandy Loam	Table 3.a.1 or field data
Saturated Hydraulic Conductivity (K_{sat}), in/hr	0.04	0.43	
Porosity (P), fraction	0.464	0.453	
Field Capacity (FC), fraction	0.310	0.190	
Wilting Point (WP), fraction	0.187	0.085	
Depth of Soil (D), feet	5	2.0	• D_{GW} = depth to restrictive layer • D_M depth of amended filter / planting bed
Depth of Water in Soil at:			
- Porosity (V_P), feet	2.32	0.906	*P * D*
- Field Capacity (V_{FC}), feet	1.55	0.380	*FC * D*
- Wilting Point (V_{WP}), feet	0.935	0.170	*WP * D*

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Step 3.d.1: Amended Soil in BMP (pass 2)

Characteristic	Source
Infiltration into Surface of BMP (V_{EI}), feet = _____	*Minimum of :* • $K_{sat\text{-}EI} * t$ • D_{BMP}
Surface condition: Ponded Infiltrated	*If $D_{BMP} > V_{EI}$, surface ponding occurs* *If $V_{EI} \geq D_{BMP}$ then the water is infiltrated into the amended soil.*
Surface detention volume (V_{SD}), feet = _____	$D_{BMP} - V_{EI}$

If the surface condition is infiltrated then infiltration into the amended soil appears to be a feasible option for this BMP site. Continue with Step 3.d.2 to determine if an underdrain is needed. If surface condition is ponded, then proceed directly to basin BMP design (Step 3e).

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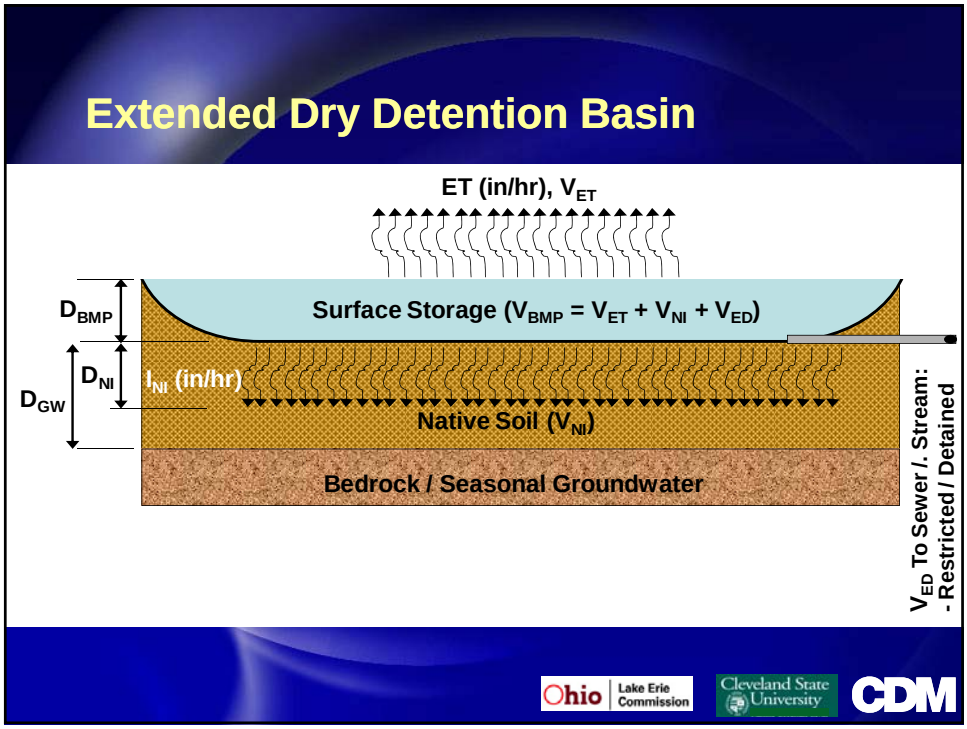
Step 3.d.2: Determine Infiltration, Evaporation and Soil Moisture within BMP

Characteristic	Source
Subsurface Dewatering Period (t_{DW}), days = _____	*Up to 3 days of subsurface dewatering typically will not affect plants within BMP*
Evapotranspiration rate (ET), in/day = _____	*Local Climate Data, check seasonal differences (see Table 3.c.1).*
Evapotranspiration in BMP (V_{ET}), feet = ____	$V_{ET} = ET * t_{DW} / 12$
Antecedent Soil Moisture at Start of Water Quality Event (V_{AM}), feet = _____	*Step 3.a.4*
Area available for infiltration into native soil surrounding planting bed (A_{NI}), ft^2 = _____	$A_{BMP} + 4 * D_M * A_{BMP}^{1/2}$
Infiltration from BMP into underlying native soil (V_{NI}), feet = _____	• If $FC_{EI} \geq V_{AM} + V_{EI} - V_{ET}$, then $V_{NI} = 0$. • If $FC_{EI} < V_{AM} + V_{EI} - V_{ET}$, then V_{NI} = *minimum of:* -- $V_{AM} + V_{EI} - V_{ET}$ -- $A_{NI} / A_{BMP} * [K_{sat\text{-}NI} * t_{DW} * 24 / 12]$
Soil Moisture at End of Dewatering Period (no Underdrain) (V_{END}), feet = _____	$V_{END} = V_{AM} + V_{EI} - V_{ET} - V_{NI}$
Determine Soil Moisture Condition: Ponded Saturated Normal Wilted (Note: Results may differ seasonally)	*Ponded*: $V_{END} > V_{P\text{-}EI}$ *(Surface Ponding expected without underdrain)* *Saturated*: $V_{FC\text{-}EI} < V_{END} < V_{P\text{-}EI}$ *(soil may go anoxic)* *Normal*: $V_{WP\text{-}EI} > V_{END} > V_{FC\text{-}EI}$ *(normal for plant growth)* *Wilted*: $V_{END} < V_{WP\text{-}EI}$ *(Soil moisture less than wilting point - plants will die)*
Underground detention volume (V_{UD}), ft = ___	Maximum of $V_{END} - V_{FC\text{-}EI}$, 0

STEP 3.e: Design Basin BMP (if soil moisture condition is Saturated or Ponded after Step 3.d.)

Characteristic	Source
Extended Detention Volume (V_{ED}), feet = ___	$V_{SD} + V_{UD}$, *Steps 3.c.3 and 3.d.2*
Soil Moisture at End of Dewatering Period (with Underdrain), feet = _____	$V_{END} = V_{AM} + V_{EI} - V_{ET} - V_{NI} - V_{UD}$
Determine Soil Moisture Condition: Ponded Saturated Normal Wilted	*Ponded*: $V_{END} > V_{P\text{-}EI}$ *(Surface Ponding expected without underdrain)* *Saturated*: $V_{FC\text{-}EI} < V_{END} < V_{P\text{-}EI}$ *(soil may go anoxic)* *Normal*: $V_{WP\text{-}EI} > V_{END} > V_{FC\text{-}EI}$ *(normal for plant growth)* *Wilted*: $V_{END} < V_{WP\text{-}EI}$ *(Soil moisture less than wilting point - plants will die)*


Extended Dry Detention Basin
ET (in/hr), V_{ET}
D_{BMP}
Surface Storage ($V_{BMP} = V_{ET} + V_{NI} + V_{ED}$)
D_{NI}
I_{NI} (in/hr)
D_{GW}
Native Soil (V_{NI})
Bedrock / Seasonal Groundwater
V_{ED} To Sewer /. Stream:
- Restricted / Detained
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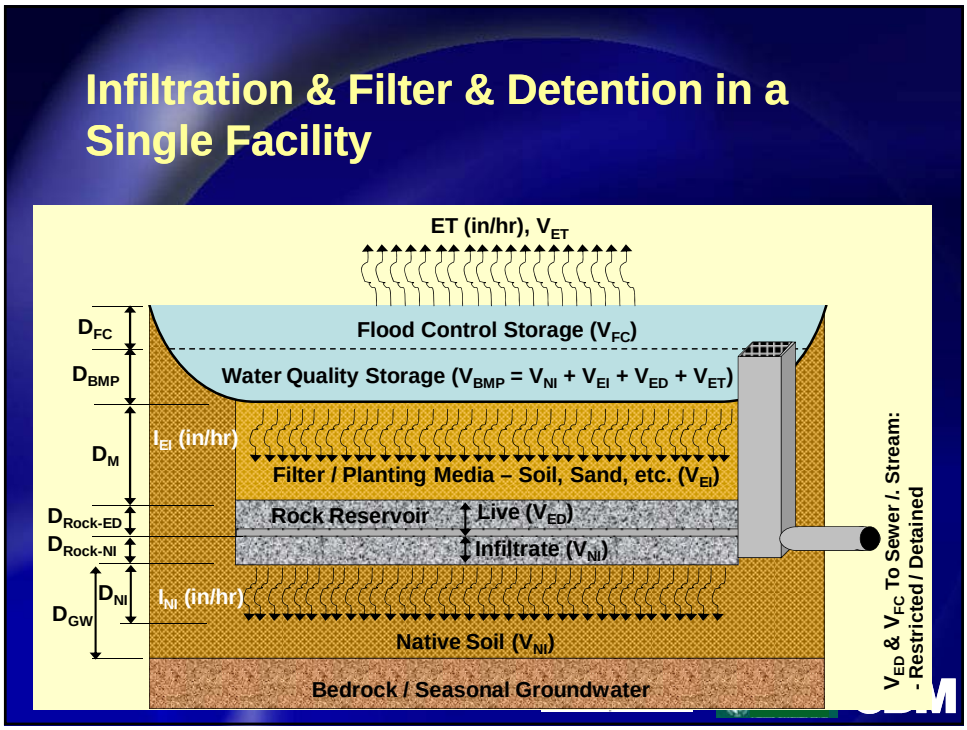

Infiltration & Filter & Detention in a Single Facility
ET (in/hr), V_{ET}
D_{FC}
Flood Control Storage (V_{FC})
D_{BMP}
Water Quality Storage ($V_{BMP} = V_{NI} + V_{EI} + V_{ED} + V_{ET}$)
D_M
I_{EI} (in/hr)
Filter / Planting Media – Soil, Sand, etc. (V_{EI})
$D_{Rock-ED}$
Rock Reservoir
Live (V_{ED})
$D_{Rock-NI}$
Infiltrate (V_{NI})
D_{NI}
I_{NI} (in/hr)
D_{GW}
Native Soil (V_{NI})
Bedrock / Seasonal Groundwater
V_{ED} & V_{FC} To Sewer /. Stream:
- Restricted / Detained

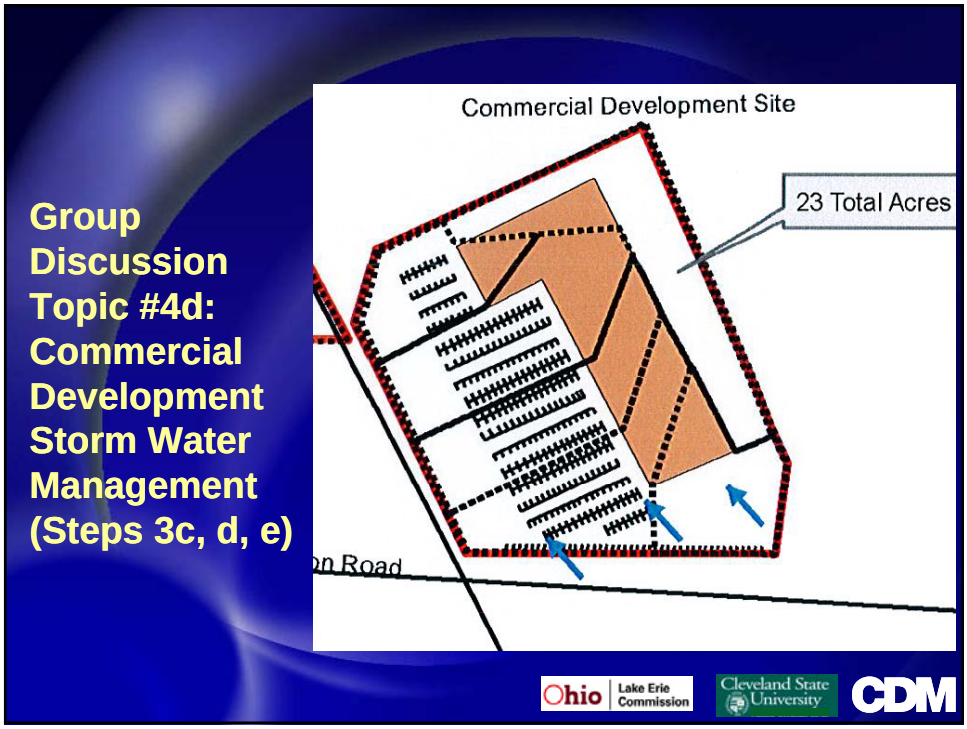
Group Discussion Topic #4c: Amended Soil Infiltration / Detention Facility (Steps 3c, d, e)

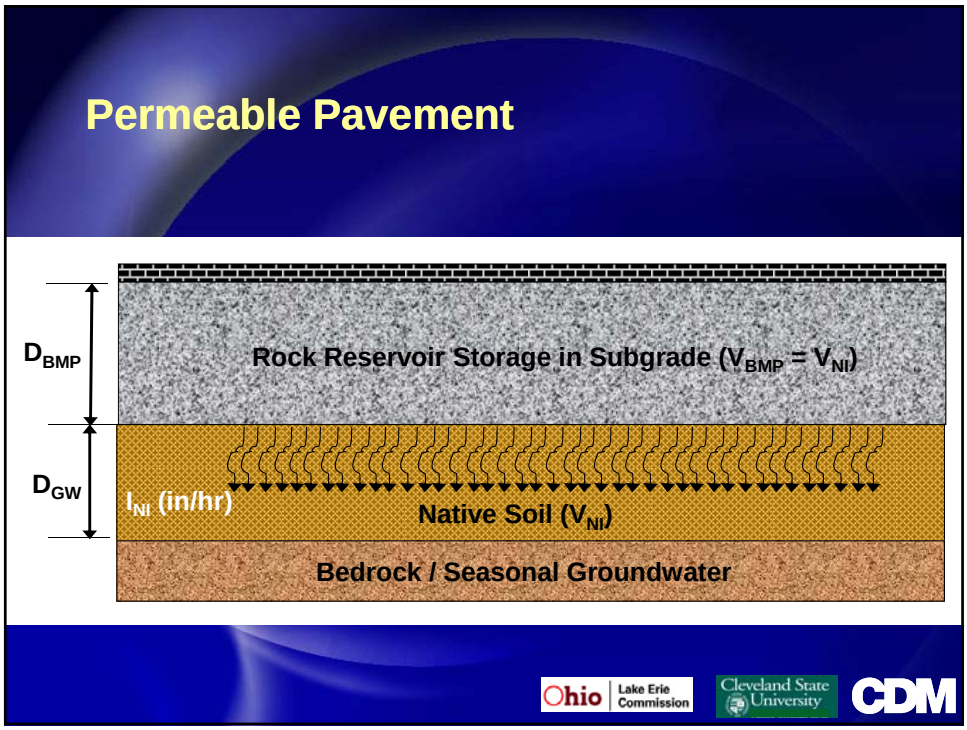
Group Discussion Topic #4c: Amended Soil Infiltration / Detention Facility (Steps 3c, d, e)

Problem Statement #3

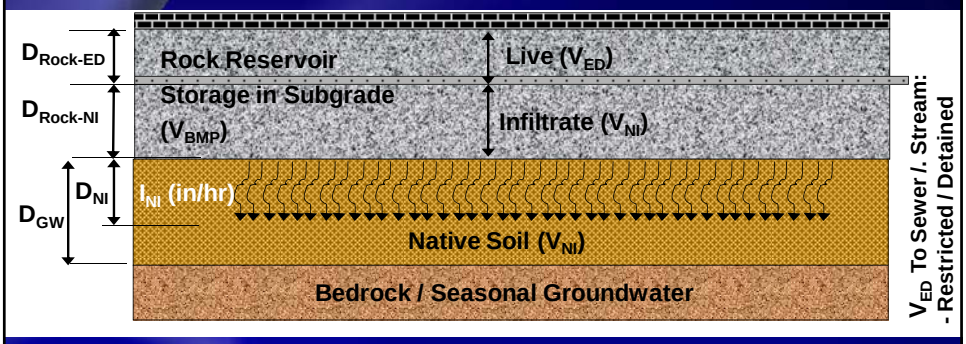
Sub-area A provides opportunity to infiltrate stormwater through a possible bio-retention cell. Locate and evaluate functionality of a bioretention facility within this sub-area by using worksheets 3.a-3.e to determine control volumes (3.a), maximize native infiltration (3.c), evaluate amended soil infiltration (3.d), and design a basin BMP (3.e) if necessary. Assume that all drainage from this sub-area is conveyed via conventional methods directly to the bioretention facility. Base design off the following parameters:

Catchment area (A_R)	*36 acres*
BMP surface area(A_{BMP})	*3 acres*
Impervious fraction (i_T)	*0.6*
Time of Concentration(T_c)	*30 minutes*
Allowable surface ponding time (t)	*24 hours*
Subsurface Dewatering Period (t_{DW})	*1 days*
Evapotranspiration rate (ET)	*0.11 in/day*
Amended soil type	*Loamy Sand*
Depth of amended soil	*5 feet*


Group Discussion Topic #4d: Commercial Development Storm Water Management (Steps 3c, d, e)
Commercial Development Site
23 Total Acres
on Road
Ohio Lake Erie Commission
Cleveland State University
CDM


Permeable Pavement
D_{BMP}
D_{GW}
Rock Reservoir Storage in Subgrade ($V_{BMP} = V_{NI}$)
I_{NI} (in/hr)
Native Soil (V_{NI})
Bedrock / Seasonal Groundwater
Ohio Lake Erie Commission
Cleveland State University
CDM

Permeable Pavement with Infiltration and Detention



Group Discussion Topic #4d: Commercial Development Storm Water Management (Steps 3c, d, e)

Problem Statement #4

A commercial development is proposed east of the residential development. The development will include one building, a parking lot, and lawn areas. Using worksheets 3.a- 3.e to determine control volumes (3.a), maximize native infiltration (3.c), evaluate amended soil infiltration (3.d), and design a basin BMP (3.e) if necessary; attempt to incorporate pervious pavement within a sub-area of the commercial development according to the following parameters:

Catchment area (A_R)	*4 acres*
BMP surface area(A_{BMP})	*1.5 acres*
Impervious fraction (i_T)	*0.6*
Time of Concentration(T_c)	*3 minutes*
Allowable surface ponding time (t)	*1 hour*
Subsurface Dewatering Period (t_{DW})	*1 day*
Amended soil type	*Sand*
Depth of amended soil	*2.5 feet*