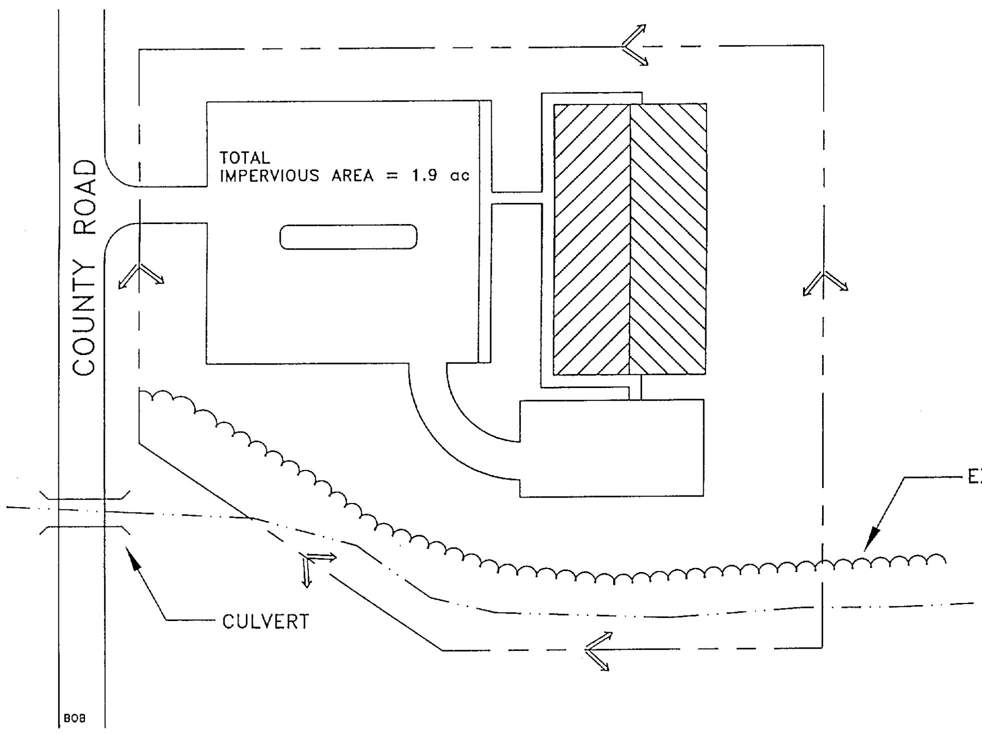
APPENDIX D-5

Enhanced Swale Design Example



Base Data	Hydrologic Data		
		Pre	**Post**
Site Area = Total Drainage Area (A) = 3.0 ac	CN	70	88
Impervious Area = 1.9 ac; or I =1.9/3.0 = 63.3%	t_c	.39	.20
Soils Type “C”			

Figure 1. Etowah Recreation Center Site Plan

This example focuses on the design of a dry swale to meet the water quality treatment requirements of the site. Channel protection and overbank flood control is not addressed in this example other than quantification of preliminary storage volume and peak discharge requirements. It is assumed that the designer can refer to the previous pond example in order to extrapolate the necessary information to determine and design the required storage and outlet structures to meet these criteria. In general, the primary function of dry swales is to provide water quality treatment and groundwater recharge and not large storm attenuation. As such, flows in excess of the water quality volume are typically routed to bypass the facility. Where quantity control is required, the bypassed flows can be routed to conventional detention basins (or some other facility such as underground storage vaults).

Computation of Preliminary Stormwater Storage Volumes and Peak Discharges

The layout of the Etowah Recreation Center is shown in Figure 1.

Two swales will be designed to carry flow to the existing stream, one around each side of the development.

Step 1 -- Compute runoff control volumes from the Unified Stormwater Sizing Criteria

Compute Water Quality Volume (WQ_v):

- Compute Runoff Coefficient, Rv

  $R_v = 0.05 + (63.3)(0.009) = 0.62$

- Compute WQ_v

  $WQ_v = (1.2”)(R_v)(A) / 12$
  $= (1.2”)(0.62)(3.0ac)(43{,}560ft^2/ac)(1ft/12in)$
  $= \underline{8{,}102}\ ft^3 = 0.19$ ac-ft

Compute Stream Channel Protection Volume (Cp_v):

For stream channel protection, provide 24 hours of extended detention for the 1-year event.

In order to determine a preliminary estimate of storage volume for channel protection and overbank flood control, it will be necessary to perform hydrologic calculations using approved methodologies. This example uses the NRCS TR-55 methodology presented in Section 2.1 to determine pre- and post-development peak discharges for the 1-yr, 25-yr, and 100-yr 24-hour return frequency storms.

- Per attached TR-55 calculations (Figures 2 and 3)

Condition	CN	Q_{1-year}	Q_{1-year}	$Q_{25-year}$	$Q_{100\ year}$
		Inches	*cfs*	*cfs*	*cfs*
Pre-developed	70	0.9	2.3	9.0	12.0
Post-Developed	88	2.1	8.1	19.0	25.0

- Utilize modified TR-55 approach to compute channel protection storage volume

  Initial abstraction (Ia) for CN of 88 is 0.27: [Ia = (200/CN - 2)]

  Ia/P = (0.27)/ 3.4 inches = 0.08
  T_c = 0.20 hours
  q_u = 850 csm/in

  Knowing q_u and T (extended detention time), find q_o/q_I for a Type II rainfall distribution.

Peak outflow discharge/peak inflow discharge (q_o/q_i) = 0.022

For a Type II rainfall distribution,

$Vs/Vr = 0.683 - 1.43(q_o/q_i) + 1.64(q_o/q_i)^2 - 0.804(q_o/q_i)^3$
Where Vs equals channel protection storage (Cp_v) and Vr equals the volume of runoff in inches.

Vs/Vr = 0.65

Therefore, Vs = Cp_v = 0.65(2.1")(1/12)(3 ac) = 0.34 ac-ft = 14,810 ft^3

Determine Overbank Flood Protection Volume (Q_{p25}):

For a Q_{in} of 19 cfs, and an allowable Q_{out} of 9 cfs, the Vs necessary for 25-year control is 0.38 ac-ft or 16,553 ft^3, under a developed CN of 88. Note that 6.5 inches of rain fall during this event, with 5.1 inches of runoff.

Analyze for Safe Passage of 100 Year Design Storm (Q_f):

At final design, prove that discharge conveyance channel is adequate to convey the 100-year event and discharge to receiving waters, or handle it with a peak flow control structure, typically the same one used for the overbank flood protection control.

Table 1 Summary of General Design Information for Etowah Recreation Center

Symbol	Control Volume	Volume Required (cubic feet)	Notes
WQ_v	Water Quality	8,102	
Cp_v	Channel Protection	14,810	
Q_{p25}	Overbank Flood Protection	16,553	
Q_f	Extreme Flood Protection	NA	Provide safe passage for the 100-year event in final design

PEAK DISCHARGE SUMMARY				
JOB:	Etowah Recreation Center			EWB
DRAINAGE AREA NAME:	Pre-Developed Conditions			3-Jan-00
COVER DESCRIPTION	SOIL NAME	GROUP A,B,C,D?	CN from TABLE 2.1.5-1	AREA (In acres)
woods (good cond.)		C	70	3.00 Ac.
		AREA SUBTOTALS:		3.00 Ac.
Time of Concentration	Surface Cover	Manning 'n'	Flow Length	Slope
2-Yr 24 Hr Rainfall = 4.1 In	Cross Section	Wetted Per	Avg Velocity	Tt (Hrs)
Sheet Flow	dense grass	'n'=0.24	150 Ft.	1.50% 0.33 Hrs
Shallow Flow	unpaved		500 Ft. 2.28 F.P.S.	2.00% 0.06 Hrs.
Channel Flow				
Total Area in Acres =	3.00 Ac.	Total Sheet Flow=	Total Shallow Flow=	Total Channel Flow =
Weighted CN =	70			
Time Of Concentration =	0.39 Hrs.	0.33 Hrs.	0.06 Hrs.	0.00 Hrs.
Pond Factor =	1	RAINFALL TYPE II		
STORM	*Precipitation* (P) inches	*Runoff* (Q)	Qp, PEAK DISCHARGE	TOTAL STORM Volumes
1 Year	3.4 In.	0.9 In.	2.3 CFS	10,049 Cu. Ft
2 Year	4.1 In.	1.4 In.	3.5 CFS	15,064 Cu. Ft
5 Year	4.8 In.	1.9 In.	5 CFS	20,574 Cu. Ft
10 Year	5.5 In.	2.4 In.	7 CFS	26,459 Cu. Ft
25 Year	6.5 In.	3.2 In.	9 CFS	34,748 Cu. Ft
50 Year	7.2 In.	3.8 In.	10 CFS	41,221 Cu. Ft
100 Year	7.9 In.	4.4 In.	12 CFS	47,868 Cu. Ft

Figure 2. Etowah Recreation Center Pre-Developed Conditions

PEAK DISCHARGE SUMMARY				
JOB:	Etowah Recreation Center			EWB
DRAINAGE AREA NAME:	Post-Development Conditions			3-Jan-00
COVER DESCRIPTION	SOIL NAME	GROUP A,B,C,D?	CN from TABLE 2.1.5-1	AREA (In acres)
open space (good cond.)		C	74	0.50 Ac.
woods (good cond.)		C	70	0.60 Ac.
impervious		C	98	1.90 Ac.
		AREA SUBTOTALS:		3.00 Ac.
Time of Concentration	Surface Cover	Manning 'n'	Flow Length	Slope
2-Yr 24 Hr Rainfall = 4.1 In	Cross Section	Wetted Per	Avg Velocity	Tt (Hrs)
Sheet Flow	dense grass	'n'=0.24	50 Ft.	1.50%
				0.14 Hrs
Shallow Flow	paved		600 Ft.	2.00%
			2.87 F.P.S.	0.06 Hrs.
Channel Flow		'n'=0.024	50 Ft.	2.00%
Hydraulic Radius =0.75	X-S estimated	WP estimated	7.25 F.P.S.	0.00 Hrs.
Total Area in Acres =	3.00 Ac.	Total Sheet Flow= 0.14 Hrs.	Total Shallow Flow= 0.06 Hrs.	Total Channel Flow = 0.00 Hrs.
Weighted CN =	88			
Time Of Concentration =	0.20 Hrs.			
Pond Factor =	1	RAINFALL TYPE II		
STORM	Precipitation (P) inches	Runoff (Q)	Qp, PEAK DISCHARGE	TOTAL STORM Volumes
1 Year	3.4 In.	2.1 In.	8.1 CFS	23,320 Cu. Ft.
2 Year	4.1 In.	2.8 In.	10.6 CFS	30,527 Cu. Ft.
5 Year	4.8 In.	3.5 In.	13 CFS	37,890 Cu. Ft.
10 Year	5.5 In.	4.2 In.	16 CFS	45,356 Cu. Ft.
25 Year	6.5 In.	5.1 In.	19 CFS	55,422 Cu. Ft.
50 Year	7.2 In.	5.8 In.	22 CFS	63,030 Cu. Ft.
100 Year	7.9 In.	6.5 In.	25 CFS	70,676 Cu. Ft.

Figure 3. Etowah Recreation Center Post-Developed Conditions

Step 2 -- Determine if the development site and conditions are appropriate for the use of an enhanced dry swale system

Existing ground elevation at the facility location is 922.0 feet, mean sea level. Soil boring observations reveal that the seasonally high water table is at 913.0 feet and underlying soils are silt loams (ML). Adjacent creek invert is at 912.0 feet.

Step 3 -- Confirm local design criteria and applicability

There is a local requirement that the 25-year storm is contained within the top of banks of all channels, including these enhanced swale controls.

No additional local criteria are applicable.

Step 4 -- Determine pretreatment volume

Size two shallow forebays at the head of the swales equal to 0.05" per impervious acre of drainage (each) (Note, total recommended pretreatment requirement is 0.1"/imp acre). (1.9 ac) (0.05") (1ft/12") (43,560 sq ft/ac) = 344.9 ft^3

Use a 2' deep pea gravel drain at the head of the swale to provide erosion protection and to assist in the distribution of the inflow. There will be no side inflow nor need for pea gravel diaphragm along the sides.

Step 5 -- Determine swale dimensions

Required: bottom width, depth, length, and slope necessary to store WQ_v with less than 18" of ponding (see Figure 5 for representative site plan).

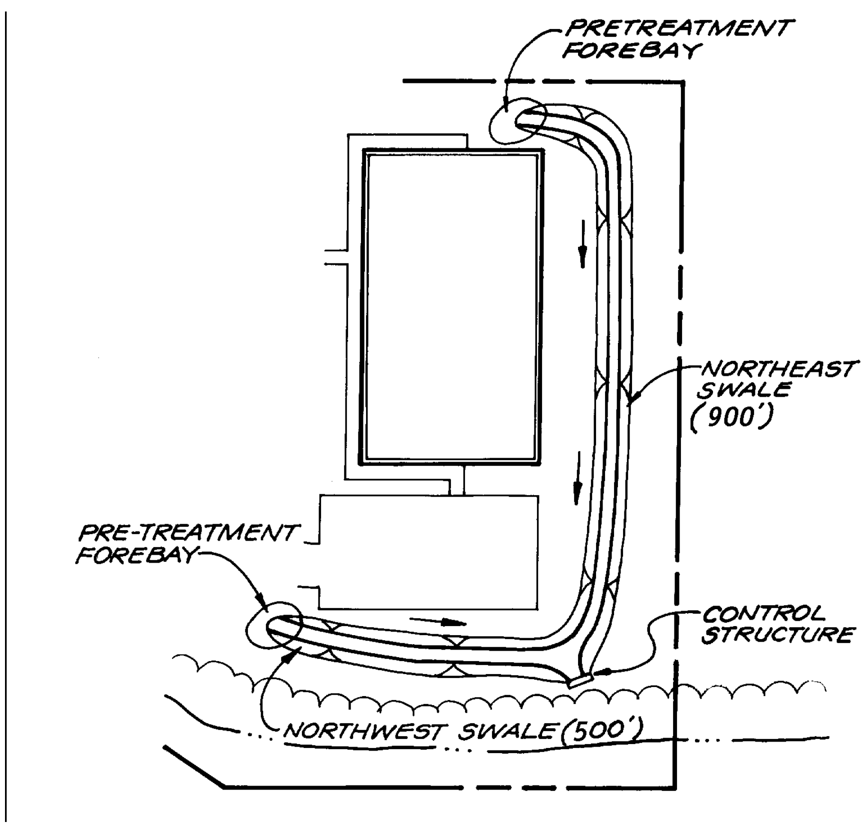


Figure 5. Enhanced Dry Swale Site Plan

Assume a trapezoidal channel with a maximum WQ_v depth of 18". Control for this swale will be a shallow concrete wall with a low flow orifice, trash rack located per Figures 5 and 6. Per the site plan, we have about 1,400' of swale available, if the swale is put in with two tails. The outlet control will be set at the existing invert minus three feet (922.0 - 3.0 = 919.0). The existing uphill invert for the northwest fork is 924.0 (length of 500'), the invert for the northeast fork is 928.0 (at a length of 900').

Slope of northwest fork is (924 - 919)/500' = 0.01 or 1.0%
Slope of northeast fork is (928 - 919)/900' = 0.01 or 1.0%

Minimum slope is 1.0 % [okay]

For a trapezoidal section with a bottom width of 6', a WQ_v average depth of 9", 3:1 side slopes, compute a cross sectional area of (6') (0.75') + (0.75') (2.25') = 6.2 ft^2 (see Figure 7).

(6.2 sq ft) (1,400 ft) = 8,680cubic feet [> WQ_v of 8,102 ft^3; OK]

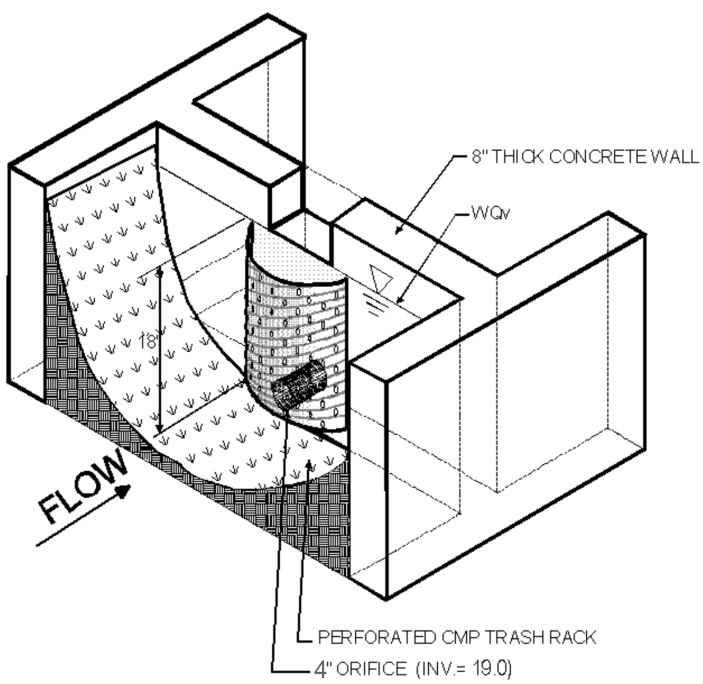


Figure 6 Control Structure at End of Swale

Step 6 -- Compute number of check dams (or similar structure) required to detain WQ_v (see Figure 7)

For the northwest fork, 500 ft @ 1.0% slope, and maximum depth at 18”, place checkdams at: 1.5’/0.01 = 150' place at 150’, 4 required

For the northeast fork, 900 ft @ 1.0% slope, and maximum 18" depth, place checkdams at 1.5’/0.01 = 150’ place at 150’, 6 required

Step 7 -- Calculate draw-down time

In order to ensure that the swale will draw down within 24 hours, the planting soil will need to pass a maximum rate of 1.5’ in 24 hours (k = 1.5’ per day). Provide 6” perforated underdrain pipe and gravel system below soil bed (see Figure 7)

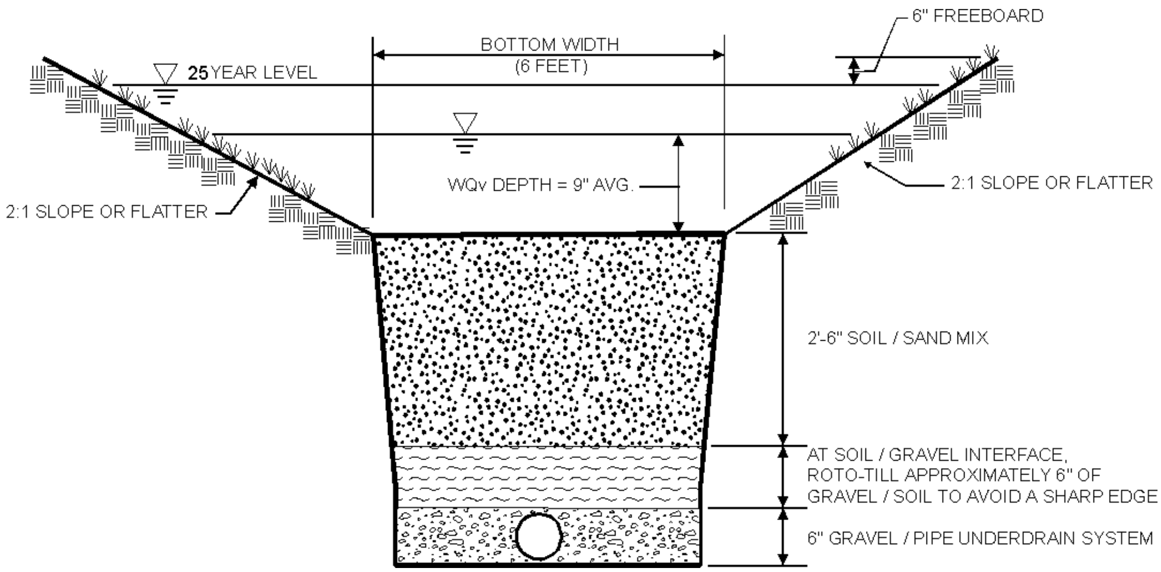


Figure 7 Trapezoidal Dry Swale Section

Step 8 -- Check 2-year and 25-year flows for velocity erosion potential and freeboard

Given the local requirements to contain the 25-year flow within banks with freeboard. In this example only the 25-year flow will be checked assuming that lower flows will be handled. The 25-year flow is 19.0 cfs, assume that 30% goes through northwestern swale (5.7 cfs) and 70% goes through the northeastern swale (13.3 cfs). Design for the larger amount (13.3 cfs). From separate computer analysis, with a slope of 1.0%, the 25-year velocity will be 3.3 feet-per-second at a depth of .65 feet, provide an additional .5’ of freeboard above top of checkdams or about 1.2' (total channel depth = 2.7’).

Find 25-year overflow weir length required: (weir eq. $Q = CLH^{3/2}$), where C = 3.1, Q_{25} = 19 cfs, H =1.2; Rearranging the equation yields:

$L = 19 \text{ cfs} / (3.1 * 1.2^{1.5}) = 4.7'$ Use 5 ft

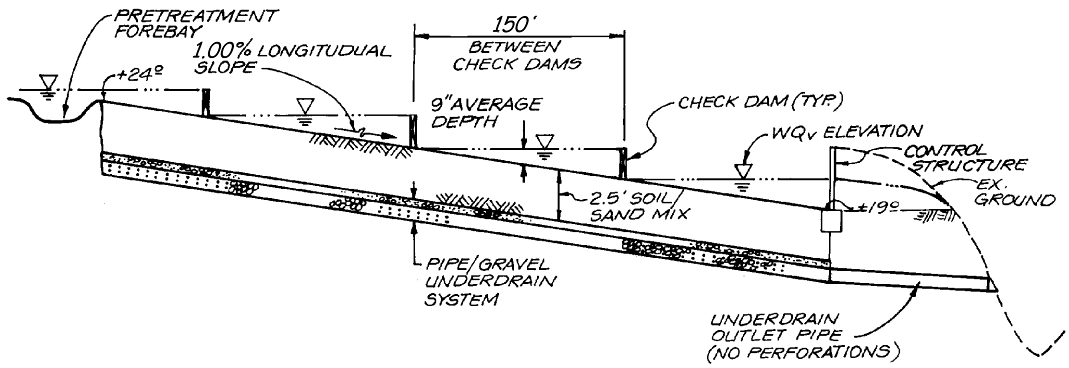


Figure 8 Profile of Northwest Fork Dry Swale

Step 9 -- Design low flow orifice at downstream headwall and checkdams (See Figure 6)

Design orifice to pass 8,102 cubic feet in 6 hours.

8,102 cubic feet/ [(6 hours) (3600 sec/hour)] = 0.4 cfs
Use Orifice equation: $Q = CA(2gh)^{1/2}$

Assume h = 1.5'

$A = (0.4 \text{ cfs}) / [(0.6) ((2) (32.2 \text{ ft/s}^2) (1.5'))^{1/2}]$

A = 0.068 sq ft, dia = 0.29 feet or 3.6" use 4" orifice

Provide 3" v-notch slot in each check dam

Step 10 – Design inlets, sediment forebay(s), and underdrain system

See Figure 8

Step 11 – Prepare Vegetation and Landscaping Plan

This page left intentionally blank