CHAPTER 8

WATER QUALITY
BEST MANAGEMENT PRACTICES

8.5 Example Design Applications

8.5.1 Example Design – Infiltration Trenches

All equations used in the following section are fully documented and discussed in Maryland's Department of Natural Resources Standards and Specifications for Infiltration Practices, 1984 (See Reference #2).

Site Layout

The site for an infiltration trench consists of two areas:

1. the portion of the watershed that contributes direct runoff to the infiltration trench, which is denoted as A_u; and
2. the portion of the watershed allocated to the basin (does not contribute runoff to the trench), which is denoted as A_b. The subscript u and b are used to indicate the upland and basin drainage areas, respectively.

Design Procedure

Step 1 Calculate the volume of runoff, in inches, from the first 1.2 inches of rainfall within the proposed development, ΔQ_u.

Step 2 Compute the maximum allowable trench depth (d_{max}) from the feasibility equation 8.5.1.-1

$$d_{\max} = Ft_s / V_r \qquad \textbf{Eq. 8.5.1-1}$$

Where: F = minimum infiltration rate, in/hr
t_s = storage time, hr
V_r = void ratio in soil or rock

Step 3 Select the trench design depth (d_t) based on the depth that is at least two feet above the seasonal high groundwater table, or a depth less than or equal to d_{max}, whichever results in the smaller depth.

Step 4 Compute the trench surface area (A_t) from Equation 8.5.2:

$$A_t = (\Delta Q_u A_u)/(V_r d_t - P + Ft_s) \qquad \textbf{Eq. 8.5.1-2}$$

Where: A_t = surface area of trench, ft^2
P = rainfall depth, ft
Other variables previously defined

Step 5 Compute the trench width or length equation 8.5.1-3.

$$L_t = (\Delta Q_u A_u) / [(V_r d_t - P + F t_s) W_t] \qquad \textbf{Eq. 8.5.1-3}$$

Where: L_t = length of trench, ft
W_t = width of trench, ft
Other variables previously defined

In the event that the side walls of the trench must be sloped for stability during construction, the surface dimensions of the trench area should be based on equation 8.5.1-4:

$$A_t = (L_t - Zd_t)(W_t - Zd_t) \qquad \textbf{Eq. 8.5.1-4}$$

Where: Z = trench side slope ratio

The design procedure would begin by selecting a top width (W_t) that is greater than $2Zd_t$, for a specified side ratio (Z). The length (L_t) is then determined as:

$$L_t = Zd_t + (A_t) / (W_t - Zd_t) \qquad \textbf{Eq. 8.5.1-5}$$

<u>Example Application</u>

An infiltration trench with surface inlets will be used to control the first 1.2 inches of rainfall from the impervious surfaces within a 6 acre commercial site. Following are the calculations for the surface area of the trench.

Design Data: F = 1.02 in/hr
V_r = 0.4
t_s = 24 hours
Depth to groundwater = 12 feet
Depth to bedrock = 18 feet

Step 1 Calculate the volume of runoff, in inches, from the first 1.2 inches of rainfall within the proposed development, ΔQ_u.

For the proposed development, 63 percent (0.63) of the total development is covered by impervious surfaces. Thus the volume that must be controlled would be as follows:

ΔQ_u = 1.2 in (0.05 + 63 * 0.009) = 1.2 in (0.617) = 0.74 inches

Step 2 Compute the maximum allowable trench depth (d_{max}) by the feasibility formula:

$d_{max} = Ft_s/V_r$

$d_{max} = (1.02)(24)/0.4 = 61.2$ in = 5.1 ft

For this example the depth to the groundwater table is 12 feet and the depth to bedrock is 18 feet.

Step 3 Select a trench design depth less than d_{max} and at least two feet above the groundwater table (subtract 1.5 feet for the overlying soil cover with surface inlets).

Select $d_t = 3.0$ ft

Step 4 Compute the trench surface area (A_t) by the equation:

$A_t = (\Delta Q_u A_u)/(V_r d_t - P + Ft_s)$

Where: A_u = 6 acres x 43560 ft^2/acre = 261,360 ft^2
V_r = 0.40
t_s = 24 hours
F = 1.02 in/hr
= 8.5 ft
ΔQ_u = 0.74 in 0.062 ft
P = 1.2 in = 0.1 ft
A_t = [(0.062)(261,360)]/[(0.40)(3) – 0.1 + (1.02/12 x 24)]
A_t = 5,161 ft^2

8.5.2 Example Design – Grassed Swales

Site Layout

The site layout will consist of the portion of the watershed that contributes direct runoff to the swale area or the upland area, which is denoted as A_u; and the portion of the watershed allocated for swale storage, which is denoted as A_s. It is important to note that the upland area (A_u) does not include the area allotted to the swale surface (A_s). Swale locations are usually either on the side or back of the property line or along the side of roadways (not in the road right-of-way). Installation of berms or check dams at certain intervals along the length of eh swale will result in storage.

Design Procedure

Step 1 Calculate the volume of runoff, from the first 1.2 inches of rainfall within the proposed development , ΔQ_u.

Step 2 Compute the maximum allowable swale check dam check dam depth (d_{max}) from the feasibility equation 8.5.2-1.

$$d_{\max} = Ft_s / V_r = FT_p \qquad \textbf{Eq. 8.5.2-1}$$

Where: F = minimum infiltration rate, in/hr
t_s = maximum storage time for stone aggregate reservoir, hr
V_r = void ratio in soil or rock
T_p = maximum allowable ponding time for surface storage, hr

Step 3 Select the swale design depth (d_s) based on the depth that is at least two feet above the seasonal high groundwater table, or a depth less than or equal to d_{max}, whichever results in the smaller depth.

Step 4 The swale surface area dimensions can be determined from Equations 8.5.2-2 and 8.5.2-3. The bottom width (W_b) is selected along with the side slope ratio (Z), and depth of check dam (d_s). The swale top width (W) and total hydraulic length (L_T) may be computed as:

$$W = W_b + 2d_s Z \qquad \textbf{Eq. 8.5.2-2}$$

$$LT = [\Delta Q_u A_u] / [(ds/4)(W + W_b) + W(Ft_s - P)] \qquad \textbf{Eq. 8.5.2-3}$$

Where: P = rainfall depth

Other variables defined above.

Step 5 The maximum required spacing between check dams in computed as:

$$L = d_s / S_s \qquad \textbf{Eq. 8.5.2-4}$$

Where: S_s = bottom slope of swale, ft/ft

Step 6 The number of check dams needed to impound and store the runoff volume is determined as:

$$N_s = LT / L \qquad \textbf{Eq. 8.5.2-5}$$

Where: L = length of swale behind each check dam, ft

Step 7 If L_t is restricted by the site layout, the level of control provided by the swales is determined by:

$$Q_s = V_w / A_u \qquad \textbf{Eq. 8.5.2-6}$$

Where: V_w = $[d_s(W + W_b)L]\ [N_s]/4$
Q_s = runoff storage depth
V_w = volume of swale storage

Example Application

Low density residential lots of 3/4 acres are to be developed. A total of 4 lots will be created. The site will be designed to be managed with grassed swales with check dams located along the back of the lots. The total area of the development is 3.0 acres with 20% impervious area and 80% pervious area. Following are the calculation for the swale design.

Design Data:		
	F	= 2.41 in/hr
	V_r	= 0.4
	T_p	= 24 hours
	Depth to groundwater	= 12 feet
	Depth to bedrock	= 14 feet

Step 1 Calculate the volume of runoff, in inches, from the first 1.2 inches of rainfall within the proposed development, ΔQ_u.

For the proposed development, 20 percent (0.20) of the total development is covered by impervious surfaces. Thus the volume that must be controlled would be as follows:

$$\Delta Q_u = 1.2 \text{ in } (0.05 + 20 * 0.009) = 0.276 \text{ in}$$

and the required storage volume would be:

$$V = (0.276 \text{ in} / 12) * 3 \text{ ac} * 43560 = 3006 \text{ ft}^3$$

Step 2 Compute the maximum allowable swale depth (d_{max}) from the feasibility equation:

$$d_{max} = FT_p$$

$$d_{max} = 2.41(24) = 57.84 \text{ in} = 4.82 \text{ ft}$$

Step 3 Select the swale check dam design depth (d_s); the depth to the groundwater table and bedrock is greater than d_{max}.

$$d_s = 1.0 \text{ ft}$$

Step 4 Select the swale bottom width (W_b) and the swale side slope ratio (Z), assuming the same side slopes. Determine the top width (W) of the swale check dam from:

$$W = W_b + 2d_sZ$$

Where: $Z = 5\ (5h/1_v)$

$W_b = 18$ ft

$W = 18 + 2(1.0)(5) = 28$ ft

The site layout allows for a swale length of 480 feet along the back of all the lots. The total swale length (L_T) is fixed so that the volume of swale storage (V_w) may be determined from the dimensions given:

$$V_w = [d_s\ (W + W_b)\ LT]/4$$

$$V_w = [1.0\ (28 + 18)480]/4 = 5{,}520\ ft^3$$

Step 5 The number of swale check dams (N_s) that needs to be constructed to achieve the volume of storage over the total swale length will vary with the depth of each check dam (d_s), given as:

$$N_s = LT/L$$

Where L is the length of swale behind each check dam, given as:

$$L = d_s/S_S$$

Note: S_s = bottom slope of swale = 0.02 ft/ft

$$L = 1.0/0.02 = 50.0\ ft$$

Step 6 $N_s = 480/83.3 = 9.6$ (use 10 with an adjusted L of 48.0 feet*)

* the adjusted length is determined as $L = L_T/N_s$

Thus, the design storage is 5,520 ft^3 which is greater than the required storage of 3,006 ft^3 so that sufficient storage is provided by the design.

For further information on the design of infiltration measures the following references are recommended.

Stormwater Infiltration Structure Design. National Storm Association, 1415 Elliot Place, NW, Washington, D.C., 1994. Available from McTrans, University of Florida, Gainesville, Florida, 32611, (352) 392-0378. Includes a computer model for infiltration design.

Maryland Department of Natural Resources, Water Resources Administration, Stormwater Management Division, Standards and Specifications for Infiltration Practices, 1984.

8.5.3 Example Design – Bioretention Facility

Site Layout

The site layout will consist of a ½ acre residential lot with a house. The entire lot will drain to the bioretention facility. The area is assumed to have 25 percent impervious area.

Design Procedure

Step 1 Compute the Runoff Control Volumes from the Unified Design Criteria. Calculate the Water Quality Volume (WQv)

Step 2 Confirm local design criteria and applicability. Consider any special site-specific design conditions/criteria

Step 3 Determine the size of bioretention ponding filter area. The required filter bed area is computed using the following equation:

$$A_f = (WQ_v)\,(d_f) \,/\, [(k)\,(h_f + d_f)\,(t_f)] \qquad \textbf{Eq. 8.5.3-1}$$

Where: A_f = surface area of filter bed (ft^2)
d_f = filter bed depth (ft)
k = coefficient of permeability of filter media (ft/day)
h_f = average height of water above filter bed (ft)
t_f = design filter bed drain time (days)

(1.67 days or 40 hours is recommended maximum for sand filter, 48 hours for bioretention)
Use k = 0.5 ft/day

Step 4 Set design elevations and dimensions

Step 5 Design conveyances to facility

Step 6 Pretreatment volume: Pretreat with a grass filter strip. The maximum sheet flow velocity for the filter strip and ponding area is 1 foot per second. Any flow velocity higher than this should utilize a stone diaphragm at the between the contributing drainage area and the grass filter strip.

Step 7 Provide 6" perforated pipes, 10' on center with a minimum of 0.5% slope, 3/8" perforations at 6"centers, 4 holes per row.

Step 8 Emergency storm weir design. Should filter rates become reduced due to facility age or poor maintenance, an overflow weir is provided to pass the 10 year event.

Step 9. Prepare vegetation and landscaping plan. A landscaping plan for the bioretention area should be prepared to indicate how it will be established with vegetation.

<u>Example Application</u>

Step 1 Compute the Runoff Control Volumes from the Unified Design Criteria. Calculate the Water Quality Volume (WQv).

$$WQ_v = [1.2/12*(0.5+(I)*0.009)]*A$$

Where I = Percent Impervious
A = On-site area

$$WQ_v = (1.2/12)((.05+25*.009)A$$
$$WQ_v = (1.2/12)(.275).5(43560)$$
$$WQ_v = 600 \text{ cf}$$

Step 2 Confirm local design criteria and applicability. Consider any special site-specific design conditions/criteria

Step 3 Determine the size of bioretention ponding filter area. The required filter bed area is computed using the following equation:

$A_f = (WQ_v)\ (d_f) / [(k)\ (h_f + d_f)\ (t_f)]$ **Eq. 8.5.3-2**

$A_f = (600)\ (4) / [(0.5)\ (0.5 + 4)\ (2)]$

$A_f = 533\ ft^2$

Where: A_f = surface area of filter bed (ft^2)

d_f = 4 (ft)

k = 0.5 (ft/day)

h_f = 0.5 (ft)

t_f = 2 (days)

Step 4 Set design elevations and dimensions

Step 5 Design conveyances to facility

Step 6 Pretreatment volume: Pretreat with a grass filter strip. The maximum sheet flow velocity for the filter strip and ponding area is 1 foot per second. Any flow velocity higher than this should utilize a stone diaphragm at the between the contributing drain age area and the grass filter strip.

Step 7 Provide 6" perforated pipes, 10' on center with a minimum of 0.5% slope. 3.8" perforations at 6" centers, 4 holes per row.

Step 8 Emergency storm weir design. Should filter rates become reduced due to facility age or poor maintenance, an overflow weir is provided to pass the 10 year event.

Step 9 Prepare vegetation and landscaping plan. A landscaping plan for the bioretention area should be prepared to indicate how it will be established with vegetation.

END OF SECTION 8.5