### IIb. Permanent Pool Volume, Method 2 (EPA, 1986)

This method calculates the permanent pool volume required to settle out suspended solids to the basin bottom.

Step 1 - Select the WQv/runoff volume ratio ($V_{B/R}$) from **Figure 8.6** based on desired total suspended solids (TSS) removal efficiency. This ratio should be at least 4.

Step 2 - Determine the mean storm depth ($S_d$) for your region. For the Kansas City area, this depth is 0.6 inches.

Step 3 - Calculate the total impervious tributary area ($A_I$) to the EDW in acres.

Step 4 - Calculate the permanent pool volume ($V_{P2}$) from the values determined in Steps 1, 2, and 3:

$$V_{P2} = (V_{B/R} * S_d * A_i)/12$$

### IIc. Permanent Pool Design Volume

Step 1 - Choose the larger of two permanent pool volumes calculated in Parts IIa and IIb and 20% to account for sedimentation. This value is the design volume (Vp) for the permanent pool.

Step 2 - Set the permanent pool volume allocations ($V_A$) between the forebay, micropool, low marsh, and high marsh. Recommended allocations are given in **Table 8.4**. From the percentages entered ($V_{\%}$), calculate the volumes of each zone from the total permanent pool volume determined in Step 1.

$$V_{A,Forebay} = V_{\%,Forebay} * V_P$$

$$V_{A,Micropool} = V_{\%,Micropool} * V_P$$

$$V_{A,Low\ Marsh} = V_{\%,Low\ Marsh} * V_P$$

$$V_{A,High\ Marsh} = V_{\%,High\ Marsh} * V_P$$

### III. Forebay

Step 1 - Enter forebay volume ($Vol_{FB}$) as calculated in Part IIc, Step 2.

Step 2 - Calculate the forebay depth ($Z_{FB}$) from the volume and the surface area. The forebay depth should be between 4 feet and 6 feet.

Step 3 - Ensure that the sides and bottom of the forebay are paved or hardened to ease removal of silt and sedimentation from the forebay.

### IV. Micropool

Step 1 - Enter micropool volume ($Vol_{MP}$) as calculated in Part IIc, Step 2.

Step 2 - Calculate the micropool depth ($Z_{MP}$) from the volume calculated in Step 1 and the surface area. If the micropool depth is not between 4 feet and 6 feet, adjust the surface area to achieve a depth in this range.

Step 3 - Ensure that all deep micropools are surrounded by a safety bench at least 12 feet wide.

### Va. Water Quality Outlet Type

Step 1 - Select type of water quality outlet. Water quality outlet configurations are shown on **Figures 8.7** and **8.8**.

Step 2 - Proceed to Part Vb, Vc, or Vd based on water quality outlet type selected in Step 1.

### Vb. Water Quality Outlet, Single Orifice (City of Knoxville, 2001)

Step 1 - Enter WQv depth above WQv outlet ($Z_{WQ}$).

Step 2 - Calculate the average head of the WQv over the orifice invert ($H_{WQ}$) as ½ the WQv depth:

$H_{WQ} = 0.5 * Z_{WQ}$

Step 3 - Calculate the average water quality outflow rate ($Q_{WQ}$) that would result in the entire WQv draining over a period of 40 hours:

$Q_{WQ} = (WQv * 43{,}560)/(40 * 3{,}600)$

Step 4 - Set the value of the orifice discharge coefficient ($C_O$) based on orifice geometry and thickness of riser/weir plate.

Step 5 - Calculate the required water quality outlet orifice diameter ($D_O$) from parameters determined in Steps 2, 3, and 4. Orifice diameter should be larger than 4 inches to reduce the chance for clogging. If calculated orifice diameter is less than 4 inches, use perforated riser, weir plate, or v-notch weir outlet instead of single orifice.

$D_o = 12 * 2 * (Q_{WQ}/(C_o * \pi * (2 * g * H)^{0.5}))^{0.5}$

Step 6 - To size a single water quality outlet orifice for an EDW with an irregular stage-volume relationship, use the Single Orifice Worksheet. Fill in the first column with cumulative volume values for each depth interval. The Single Orifice Worksheet uses values from Part Vb of the Main Worksheet.

Vc. Water Quality Outlet, Perforated Riser, or Plate (Urban Drainage and Flood Control District, Denver, Colorado, 2005)

Step 1 - Enter WQv depth above WQv outlet ($Z_{WQ}$).

Step 2 - Calculate the recommended maximum outlet area per row of perforations ($A_O$) based on the WQv and the depth at the basin outlet:

$A_o = WQv/(0.013 * Z_{WQ}^2 + 0.22 * Z_{WQ} - 0.10)$

Step 3 - Assuming a single column, calculate the diameter of a single circular perforation ($D_1$) for each row based on the outlet area calculated in Step 2.

Step 4 - Set the number of columns of perforations ($n_c$). Keep this number as low as possible, optimally 1. If the diameter calculated in Step 3 is greater than 2 inches, make the number of columns greater than 1.

Step 5 - Calculate the design circular perforation diameter ($D_{perf}$) based on the area calculated in Step 2 and the number of columns set in Step 4. Iteratively increase the number of columns until this design diameter is between 1 and 2 inches.

Step 6 - Calculate the horizontal perforation column spacing ($S_c$), center to center, when the number of columns is greater than 1. As long as the perforation diameter calculated in Step 5 is greater than 1, the horizontal perforation column spacing should be 4 inches.

Step 7 - Calculate the number of rows of perforations ($n_r$), center to center, based on a 4-inch vertical spacing and depth at outlet from Step 1.

Vd. Water Quality Outlet, V-Notch Weir (City of Knoxville, 2001)

Step 1 - Enter WQv depth above WQv outlet ($Z_{WQ}$).

Step 2 - Calculate the average head of the WQv over the v-notch invert ($H_{WQ}$) as ½ the WQv depth:

$H_{WQ} = 0.5 * Z_{WQ}$

Step 3 - Calculate the average water quality outflow rate ($Q_{WQ}$) that would result in the entire WQv draining over a period of 40 hours:

$Q_{WQ} = (WQv * 43{,}560)/(40 * 3{,}600)$

Step 4 - Select the value of the v-notch weir discharge coefficient ($C_v$ = 2.5 typical).

Step 5 - Calculate the required v-notch weir angle (θ) from parameters determined in Steps 2, 3, and 4. If the calculated v-notch weir angle is less than 20 degrees, set to 20 degrees.

$$\theta = 2 * \arctan (Q_{WQ}/(C_v * H_{WQ}^{5/2}))$$

Step 6 - Calculate the top width of the v-notch weir ($W_v$):

$$W_v = 2 * Z_{WQ} * \mathrm{TAN}(\theta/2)$$

Step 7 - To size a v-notch weir for an EDW with an irregular stage-volume relationship, use the V-Notch Weir Worksheet. Fill in the first column with cumulative volume values for each depth interval. The V-Notch Weir Worksheet uses values from Part Vd of the Main Worksheet.

## VI. Water Budget

Perform water budget calculations for each zone of the EDW following the techniques in Chapter 13 of the NRCS *Engineering Field Handbook* to ensure that wetland vegetation can be sustained during the growing season.

## VII. Trash Racks (Urban Drainage and Flood Control District, Denver, Colorado, 2005)

Step 1 - Calculate the total water quality outlet area ($A_{ot}$) from Vb, Vc, or Vd, whichever outlet configuration you selected.

Step 2 - Calculate the required trash rack open area ($A_t$) from the total outlet area. Figures 8.8 and 8.9 show suggested details for trash racks over perforated riser outlets.

$A_t = A_{ot} * 77 * e^{(-0.124 * D)}$ for single orifice outlet

$A_t = (A_{ot}/2) * 77 * e^{(-0.124 * D)}$ for orifice plate or perforated riser outlet

$A_t = 4 * A_{ot}$ for v-notch weir outlet

## VIII. EDW Shape

Ensure that the flow path through the EDW has a length to width ratio of at least 3:1.

## IX. EDW Side Slopes (Metropolitan Nashville – Davidson County, 2000)

Basin side slopes should be at least 4:1 (H:V) to facilitate maintenance and public safety. Side slopes should be stabilized, preferably with native vegetative cover.

## X. Vegetation (Urban Drainage and Flood Control District, Denver, Colorado, 2005)

Step 1 - EDW berms and side slope areas should be planted with native grasses or with irrigated turf to provide erosion control, depending on the local setting and needs. High and low marshes should be planted with native wetland species to promote sediment settling and biological uptake of nutrients. Vegetation is discussed in more detail in Appendix A of this manual.

Step 2 - Describe the mix and density of wetland species to be planted in the marsh areas.

## XI. Inlet (Urban Drainage and Flood Control District, Denver, Colorado, 2005)

Dissipate flow energy at the EDW inflow point(s) to limit erosion and promote particle sedimentation.

## XII. Access (Urban Drainage and Flood Control District, Denver, Colorado, 2005)

All-weather stable access to the marsh zones, forebay, micropool, and outlet works area shall be provided for maintenance vehicles. Grades should not exceed 10 percent along access paths, and a solid driving surface of gravel, rock, concrete, or gravel-stabilized turf should be provided.

TABLE 8.4
Volume Allocations in Extended Detention Wetlands

| EDW Zone | Percent of Total EDW Volume |
|---|---|
| Forebay | 20 |
| Micropool | 20 |
| Low Marsh (6" to 18" below permanent pool) | 40 |
| High Marsh (0" to 6" below permanent pool) | 20 |

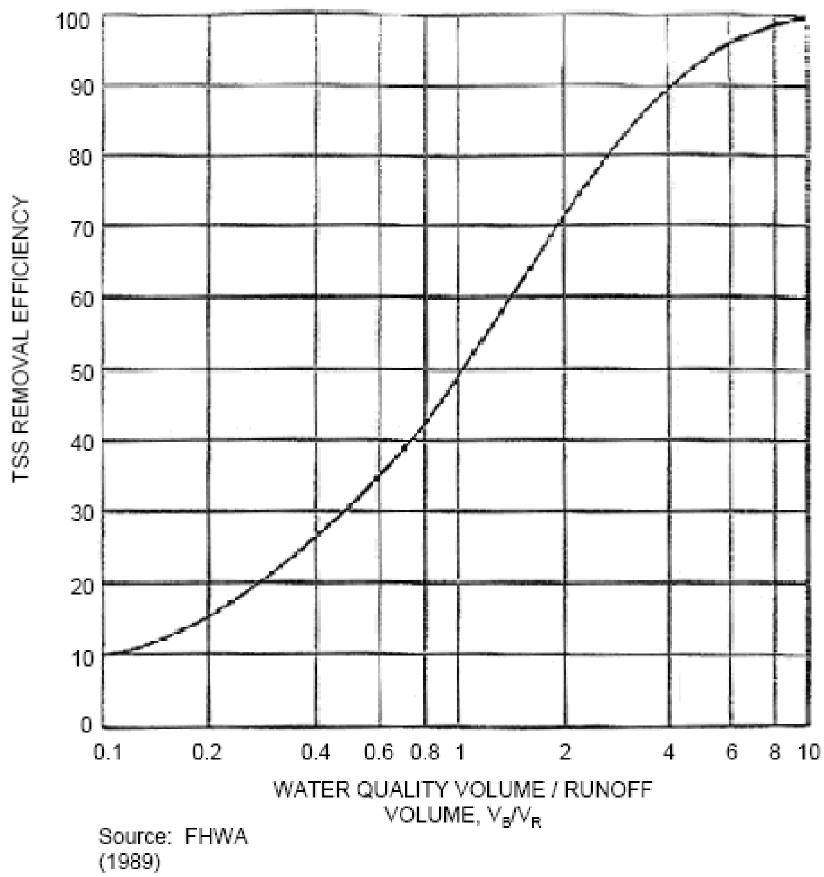



Figure 8.6 - TSS Removal Effciency of an EDW

## Design Procedure Form: Extended Detention Wetland (EDW)
## Main Worksheet

**Designer:** ___________________
**Checked By:** ___________________
**Company:** ___________________
**Date:** ___________________
**Project:** ___________________
**Location:** ___________________

**I. Basin Water Quality Volume**

| | | |
|---|---|---|
| Step 1) Tributary area to EDW, $A_T$ (ac) | $A_T$ (ac) = | 35.0 |
| Step 2) Calculate WQv using methodology in Section 6 | WQv (ac-ft) = | 2.2 |

**IIa. Permanent Pool Volume, Method 1**

| | | |
|---|---|---|
| Step 1) Average 14 day wet season rainfall, $R_{14}$ (in) | $R_{14}$ (in) = | 2.2 |
| Step 2) Rational runoff coefficient, C<br>$C = (A_I * C_I + A_P * C_P)/A_T$<br>$A_I$ = impervious area, $C_I$ = 0.95<br>$A_P$ = pervious area, $C_P$ = 0.20 | C = | 0.6 |
| Step 3) Permanent pool volume by Method 1, $V_{P1}$ (ac-ft)<br>$V_{P1} = (C * A_T * R_{14})/12$ | $V_{P1}$ (ac-ft) = | 3.9 |

**IIb. Permanent Pool Volume, Method 2**

| | | |
|---|---|---|
| Step 1) Ratio of basin volume to runoff volume, $V_{B/R}$<br>(from Figure 24; $V_{B/R}$ should be >= 4.0) | $V_{B/R}$ = | 5.0 |
| Step 2) Mean storm depth, $S_d$ (in) | $S_d$ (in) = | 0.6 |
| Step 3) Impervious tributary area, $A_I$ (ac) | $A_I$ (ac) = | 19 |
| Step 4) Permanent pool volume by Method 2, $V_{P2}$ (ac-ft)<br>$V_{P2} = (V_{B/R} * S_d * A_I)/12$ | $V_{P2}$ (ac-ft) = | 4.8 |

**IIc. Permanent Pool Design Volume**

Step 1) Permanent pool design volume, $V_P$, as larger of volumes calculated in 2a and 2b plus 20% — $V_P$ (ac-ft) = 5.7

Step 2) Permanent pool volume allocations[5]

| | EDW Zone | % of Permanent Pool Volume[5] $V_{\%}$ | Volume Allocation $V_A$ (ac-ft) |
|---|---|---|---|
| $V_{A,Forebay} = V_{\%,Forebay} * V_P$ | Forebay | 20% | 1.1 |
| $V_{A,Micropool} = V_{\%,Micropool} * V_P$ | Micropool | 20% | 1.1 |
| $V_{A,Low Marsh} = V_{\%,LowMarsh} * V_P$ | Low Marsh (6" to 18" depth) | 40% | 2.3 |
| $V_{A,High Marsh} = V_{\%,High Marsh} * V_P$ | High Marsh (0" to 6" depth) | 20% | 1.1 |

**III. Forebay**

| | | |
|---|---|---|
| Step 1) Enter forebay volume as calculated in Part IIc, Step 2 | $Vol_{FB}$ (ac-ft) = | 1.1 |
| Step 2) Forebay depth, $Z_{FB}$ (ft), should be between 4 and 6 feet | $Z_{FB}$ (ft) = | 4 |
| Step 3) Paved/hard bottom and sides? | | Yes |

## Design Procedure Form: Extended Detention Wetland (EDW)
## Main Worksheet

**Designer:** ____________________
**Checked By:** ____________________
**Company:** ____________________
**Date:** ____________________
**Project:** ____________________
**Location:** ____________________

IV. Micropool

| | | |
|---|---|---|
| Step 1) Enter micropool volume as calculated in Part IIc, Step 2 | $Vol_{MP}$ (ac-ft) = | 1.1 |
| Step 2) Micropool depth, $Z_{MP}$ (ft), should be between 4 and 6 feet | $Z_{MP}$ (ft) = | 4 |
| Step 3) Safety bench width, $W_{SB}$ (ft), should be a minimum of 12 ft | $W_{SB}$ (ft) = | 12 |

Va. Water Quality Outlet Type

| | | |
|---|---|---|
| Step 1) Set water quality outlet type:<br>Type 1 = single orifice<br>Type 2 = perforated riser or plate<br>Type 3 = v-notch weir | Outlet Type = | 1 |
| Step 2) Proceed to part Vb, Vc, or Vd based on water quality outlet type selected | | |

Vb. Water Quality Pool Outlet, Single Orifice

| | | |
|---|---|---|
| Step 1) Depth of water quality volume above permanent pool, $Z_{WQ}$ (ft) | $Z_{WQ}$ (ft) = | 0.3 |
| Step 2) Average head of water quality volume over invert of orifice, $H_{WQ}$ (ft)<br>$H_{WQ} = 0.5 * Z_{WQ}$ | $H_{WQ}$ (ft) = | 0.2 |
| Step 3) Average water quality outflow rate, $Q_{WQ}$ (cfs)<br>$Q_{WQ} = (WQv * 43{,}560)/(40 * 3{,}600)$ | $Q_{WQ}$ (cfs) = | 0.67 |
| Step 4) Set value of orifice discharge coefficient, $C_o$<br>$C_o$ = 0.66 when thickness of riser/weir plate is = or < orifice diameter<br>$C_o$ = 0.80 when thickness of riser/weir plate is > orifice diameter | $C_o$ = | 0.66 |
| Step 5) Water quality outlet orifice diameter (minimum of 4 inches), $D_o$ (in)<br>$D_o = 12 * 2 * (Q_{WQ}/(C_o * \pi * (2 * g * H)^{0.5}))^{0.5}$<br>(If orifice diameter < 4 inches, use outlet type 2 or 3) | $D_o$ (in) = | 7.71 |
| Step 6) To size outlet orifice for EDW with an irregular stage-volume relationship, use the Single Orifice Worksheet | | |

Vc. Water Quality Outlet, Perforated Riser

| | | |
|---|---|---|
| Step 1) Depth of water quality volume above permanent pool, $Z_{WQ}$ (ft) | $Z_{WQ}$ (ft) = | 0.3 |
| Step 2) Recommended maximum outlet area per row, $A_o$ (in$^2$)<br>$Ao = WQv/(0.012 * Z_{WQ}^2 + 0.14 * Z_{WQ} - 0.060)$<br>(Equation from Reference 2 for EDW with 40-hour drawdown) | $A_o$ (in$^2$) = | 2200 |
| Step 3) Circular perforation diameter per row assuming a single column, $D_1$ (in) | $D_1$ (in) = | 52.9 |
| Step 4) Number of columns, $n_c$ | $n_c$ = | 800 |
| Step 5) Design circular perforation diameter (between 1 and 2 inches), $D_{perf}$ (in) | $D_{perf}$ (in) = | 1.9 |
| Step 6) Horizontal perforation column spacing when $n_c > 1$, center to center, $S_c$<br>If $D_{perf}$ >/= 1.0 in, $S_c$ = 4 | $S_c$ (in) = | 4 |
| Step 7) Number of rows (4" vertical spacing between perforations, center to center), $n_r$ | $n_r$ = | 1 |

## Design Procedure Form: Extended Detention Wetland (EDW)
### Main Worksheet

**Designer:** ____________________
**Checked By:** ____________________
**Company:** ____________________
**Date:** ____________________
**Project:** ____________________
**Location:** ____________________

Vd. Water Quality Outlet, V-Notch Weir

Step 1) Depth of water quality volume above permanent pool, $Z_{WQ}$ (ft) — $Z_{WQ}$ (ft) = 0.3

Step 2) Average head of water quality pool volume over invert of v-notch, $H_{WQ}$ (ft)

$H_{WQ} = 0.5 * Z_{WQ}$ — $H_{WQ}$ (ft) = 0.2

Step 3) Average water quality pool outflow rate, $Q_{WQ}$ (cfs)

$Q_{WQ} = (WQv * 43{,}560)/(40 * 3{,}600)$ — $Q_{WQ}$ (cfs) = 0.7

Step 4) V-notch weir coefficient, $C_v$ — $C_v$ = 2.5

Step 5) V-notch weir angle, $\theta$ (deg)

$\theta = 2 * \arctan(Q_{WQ}/(C_v * H_{WQ}{}^{5/2}))$

V-notch angle should be at least 20 degrees. Set to 20 degrees if calculated angle is smaller. — $\theta$ (deg) = 176

Step 6) V-notch weir top width, $W_v$ (ft)

$W_v = 2 * Z_{WQ} * \mathrm{TAN}(\theta/2)$ — $W_v$ (ft) = 18.3

Step 7) To calculate v-notch angle for EDW with an irregular stage-volume relationship, use the V-notch Weir Worksheet

VI. Water Budget

Perform water budget calculations following the procedure in Chapter 13 of the NRCS Engineering Field Handbook to ensure that a permanent pool can be maintained during the growing season.

VII. Trash Racks

Step 1) Total outlet area, $A_{ot}$ (in$^2$) — $A_{ot}$ (in$^2$) = 47

Step 2) Required trash rack open area, $A_t$ (in$^2$)

$A_t = A_{ot} * 77 * e^{(-0.124 * D)}$ for single orifice outlet

$A_t = (A_{ot}/2) * 77 * e^{(-0.124 * D)}$ for orifice plate or perforated riser outlet

$A_t = 4 * A_{ot}$ for v-notch weir outlet — $A_t$ (in$^2$) = 1,382

VIII. EDW Shape

Flow path through EDW should have a minimum length-to-width ratio of 3:1 — L:W = 3.0

IX. EDW side slopes

Side slopes should be at least 4:1 (H:V) — Side Slope (H:V) = 4.0

X. Vegetation

Step 1) Check the method of vegetation planted in the EDW or describe "other"

_X_ Native Grass
___ Irrigated Turf Grass
_X_ Wetland Species in Pool
___ Other: ____________________
____________________

Step 2) Describe mix and density of wetland species. Appendix A provides plant recommendations for EDWs.

____________________________________________
____________________________________________
____________________________________________

XII. Inlet Protection

Indicate method of inlet protection/energy dissipation at EDW inlet — Rip-rap apron

## Design Procedure Form: Extended Detention Wetland (EDW)
### Main Worksheet

**Designer:** ___________________
**Checked By:** ___________________
**Company:** ___________________
**Date:** ___________________
**Project:** ___________________
**Location:** ___________________

**I. Basin Water Quality Volume**

Step 1) Tributary area to EDW, $A_T$ (ac) — $A_T$ (ac) = _______

Step 2) Calculate WQv using methodology in Section 6 — WQv (ac-ft) = _______

**IIa. Permanent Pool Volume, Method 1**

Step 1) Average 14 day wet season rainfall, $R_{14}$ (in) — $R_{14}$ (in) = _______

Step 2) Rational runoff coefficient, C — C = _______

$C = (A_I * C_I + A_P * C_P)/A_T$

$A_I$ = impervious area, $C_I$ = 0.95

$A_P$ = pervious area, $C_P$ = 0.20

Step 3) Permanent pool volume by Method 1, $V_{P1}$ (ac-ft)

$V_{P1} = (C * A_T * R_{14})/12$ — $V_{P1}$ (ac-ft) = _______

**IIb. Permanent Pool Volume, Method 2**

Step 1) Ratio of basin volume to runoff volume, $V_{B/R}$
(from Figure 24; $V_{B/R}$ should be >= 4.0) — $V_{B/R}$ = _______

Step 2) Mean storm depth, $S_d$ (in) — $S_d$ (in) = _______

Step 3) Impervious tributary area, $A_I$ (ac) — $A_I$ (ac) = _______

Step 4) Permanent pool volume by Method 2, $V_{P2}$ (ac-ft)

$V_{P2} = (V_{B/R} * S_d * A_I)/12$ — $V_{P2}$ (ac-ft) = _______

**IIc. Permanent Pool Design Volume**

Step 1) Permanent pool design volume, $V_P$, as larger of volumes calculated in 2a and 2b plus 20% — $V_P$ (ac-ft) = _______

Step 2) Permanent pool volume allocations[5]

| | EDW Zone | % of Permanent Pool Volume[5] $V_\%$ | Volume Allocation $V_A$ (ac-ft) |
|---|---|---|---|
| $V_{A,Forebay} = V_{\%,Forebay} * V_P$ | Forebay | 20% | _______ |
| $V_{A,Micropool} = V_{\%,Micropool} * V_P$ | Micropool | 20% | _______ |
| $V_{A,Low Marsh} = V_{\%,Low Marsh} * V_P$ | Low Marsh (6" to 18" depth) | 40% | _______ |
| $V_{A,High Marsh} = V_{\%,High Marsh} * V_P$ | High Marsh (0" to 6" depth) | 20% | _______ |

**III. Forebay**

Step 1) Enter forebay volume as calculated in Part IIc, Step 2 — $Vol_{FB}$ (ac-ft) = _______

Step 2) Forebay depth, $Z_{FB}$ (ft), should be between 4 and 6 feet — $Z_{FB}$ (ft) = _______

Step 3) Paved/hard bottom and sides? _______

## Design Procedure Form: Extended Detention Wetland (EDW)
### Main Worksheet

**Designer:** ____________________
**Checked By:** ____________________
**Company:** ____________________
**Date:** ____________________
**Project:** ____________________
**Location:** ____________________

IV. Micropool

Step 1) Enter micropool volume as calculated in Part IIc, Step 2 — $Vol_{MP}$ (ac-ft) = ________

Step 2) Micropool depth, $Z_{MP}$ (ft), should be between 4 and 6 feet — $Z_{MP}$ (ft) = ________

Step 3) Safety bench width, $W_{SB}$ (ft), should be a minimum of 12 ft — $W_{SB}$ (ft) = ________

Va. Water Quality Outlet Type

Step 1) Set water quality outlet type: — Outlet Type = ________
Type 1 = single orifice
Type 2 = perforated riser or plate
Type 3 = v-notch weir

Step 2) Proceed to part Vb, Vc, or Vd based on water quality outlet type selected

Vb. Water Quality Pool Outlet, Single Orifice

Step 1) Depth of water quality volume above permanent pool, $Z_{WQ}$ (ft) — $Z_{WQ}$ (ft) = ________

Step 2) Average head of water quality volume over invert of orifice, $H_{WQ}$ (ft)
$H_{WQ} = 0.5 * Z_{WQ}$ — $H_{WQ}$ (ft) = ________

Step 3) Average water quality outflow rate, $Q_{WQ}$ (cfs)
$Q_{WQ} = (WQv * 43{,}560)/(40 * 3{,}600)$ — $Q_{WQ}$ (cfs) = ________

Step 4) Set value of orifice discharge coefficient, $C_o$
$C_o$ = 0.66 when thickness of riser/weir plate is = or < orifice diameter
$C_o$ = 0.80 when thickness of riser/weir plate is > orifice diameter — $C_o$ = ________

Step 5) Water quality outlet orifice diameter (minimum of 4 inches), $D_o$ (in)
$D_o = 12 * 2 * (Q_{WQ}/(C_o * \pi * (2 * g * H)^{0.5}))^{0.5}$ — $D_o$ (in) = ________
(If orifice diameter < 4 inches, use outlet type 2 or 3)

Step 6) To size outlet orifice for EDW with an irregular stage-volume relationship, use the Single Orifice Worksheet

Vc. Water Quality Outlet, Perforated Riser

Step 1) Depth of water quality volume above permanent pool, $Z_{WQ}$ (ft) — $Z_{WQ}$ (ft) = ________

Step 2) Recommended maximum outlet area per row, $A_o$ ($in^2$)
$Ao = WQv/(0.012 * Z_{WQ}^{2} + 0.14 * Z_{WQ} - 0.060)$ — $A_o$ ($in^2$) = ________
(Equation from Reference 2 for EDW with 40-hour drawdown)

Step 3) Circular perforation diameter per row assuming a single column, $D_1$ (in) — $D_1$ (in) = ________

Step 4) Number of columns, $n_c$ — $n_c$ = ________

Step 5) Design circular perforation diameter (between 1 and 2 inches), $D_{perf}$ (in) — $D_{perf}$ (in) = ________

Step 6) Horizontal perforation column spacing when $n_c > 1$, center to center, $S_c$ — $S_c$ (in) = ________
If $D_{perf}$ >/= 1.0 in, $S_c = 4$

Step 7) Number of rows (4" vertical spacing between perforations, center to center), $n_r$ — $n_r$ = ________

## Design Procedure Form: Extended Detention Wetland (EDW)
### Main Worksheet

**Designer:** ____________________
**Checked By:** ____________________
**Company:** ____________________
**Date:** ____________________
**Project:** ____________________
**Location:** ____________________

Vd. Water Quality Outlet, V-Notch Weir

Step 1) Depth of water quality volume above permanent pool, $Z_{WQ}$ (ft) — $Z_{WQ}$ (ft) = ________

Step 2) Average head of water quality pool volume over invert of v-notch, $H_{WQ}$ (ft)

$H_{WQ} = 0.5 * Z_{WQ}$ — $H_{WQ}$ (ft) = ________

Step 3) Average water quality pool outflow rate, $Q_{WQ}$ (cfs)

$Q_{WQ} = (WQv * 43{,}560)/(40 * 3{,}600)$ — $Q_{WQ}$ (cfs) = ________

Step 4) V-notch weir coefficient, $C_v$ — $C_v$ = ________

Step 5) V-notch weir angle, $\theta$ (deg)

$\theta = 2 * \arctan(Q_{WQ}/(C_v * H_{WQ}^{5/2}))$

V-notch angle should be at least 20 degrees. Set to 20 degrees if calculated angle is smaller. — $\theta$ (deg) = ________

Step 6) V-notch weir top width, $W_v$ (ft)

$W_v = 2 * Z_{WQ} * \mathrm{TAN}(\theta/2)$ — $W_v$ (ft) = ________

Step 7) To calculate v-notch angle for EDW with an irregular stage-volume relationship, use the V-notch Weir Worksheet

VI. Water Budget

Perform water budget calculations following the procedure in Chapter 13 of the NRCS Engineering Field Handbook to ensure that a permanent pool can be maintained during the growing season.

VII. Trash Racks

Step 1) Total outlet area, $A_{ot}$ (in$^2$) — $A_{ot}$ (in$^2$) = ________

Step 2) Required trash rack open area, $A_t$ (in$^2$)

$A_t = A_{ot} * 77 * e^{(-0.124 * D)}$ for single orifice outlet

$A_t = (A_{ot}/2) * 77 * e^{(-0.124 * D)}$ for orifice plate or perforated riser outlet

$A_t = 4 * A_{ot}$ for v-notch weir outlet — $A_t$ (in$^2$) = ________

VIII. EDW Shape

Flow path through EDW should have a minimum length-to-width ratio of 3:1 — L:W = ________

IX. EDW side slopes

Side slopes should be at least 4:1 (H:V) — Side Slope (H:V) = ________

X. Vegetation

Step 1) Check the method of vegetation planted in the EDW or describe "other"

___ Native Grass
___ Irrigated Turf Grass
___ Wetland Species in Pool
___ Other: ____________________
____________________

Step 2) Describe mix and density of wetland species. Appendix A provides plant recommendations for EDWs.

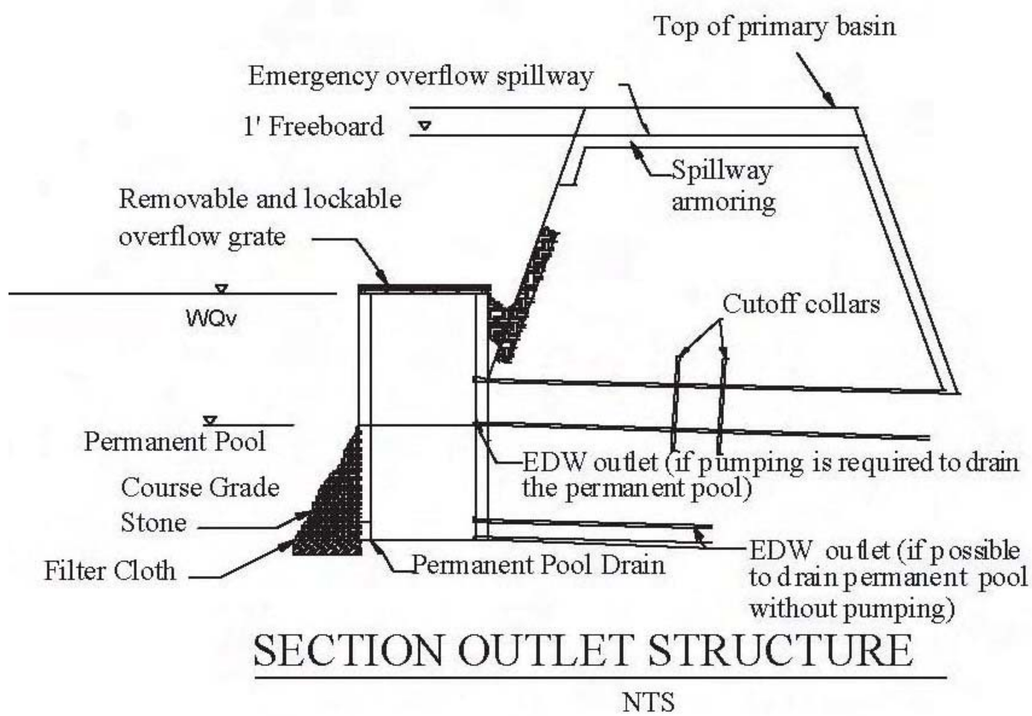
____________________________________________________________
____________________________________________________________
____________________________________________________________

XII. Inlet Protection

Indicate method of inlet protection/energy dissipation at EDW inlet ________

## Variable Dictionary

| Variable | Units | Definition |
|---|---|---|
| $A_i$ | ac | Impervious watershed area |
| $A_o$ | $in^2$ | Recommended maximum outlet area per row for perforated riser or weir plate |
| $A_{ot}$ | $in^2$ | Total open area of outlet structure |
| $A_P$ | ac | Total required permanent pool surface area |
| $A_t$ | $in^2$ | Total required trash rack open area |
| $A_T$ | ac | Tributary area to EDW |
| $A_{WQ}$ | ac | Required surface area of WQv |
| C | none | Rational runoff coefficient |
| $C_o$ | none | Orifice discharge coefficient |
| $C_v$ | none | V-Notch weir discharge coefficient |
| $D_o$ | in | Water quality outlet orifice diameter |
| $D_1$ | in | Circular perforation diameter per row, assuming a single column, for perforated riser or weir plate |
| $D_{perf}$ | in | Design circular perforation diameter for perforated riser or weir plate |
| $H_{WQ}$ | ft | Average head of WQv over invert of water quality outlet |
| $n_c$ | none | Number of columns of perforations for perforated riser or weir plate |
| $n_r$ | none | Number of rows of perforations for perforated riser or weir plate |
| $\theta$ | deg | V-Notch weir angle |
| $Q_{WQ}$ | cfs | Average WQv outflow rate |
| $R_{14}$ | in | Average 14-day wet season rainfall |
| $R_{avg}$ | in | Average wet season rainfall from period of record |
| $SA_{\%}$ | % | Permanent pool surface area percent by EDW zone |
| $SA_A$ | ac | Permanent pool surface area allocation by EDW zone |
| $S_c$ | in | Horizontal perforation column spacing for perforated riser or weir plate |
| $S_d$ | in | Mean storm depth |
| $V_{\%}$ | % | Permanent pool volume percent by EDW zone |
| $V_A$ | ac-ft | Permanent pool volume allocation by EDW zone |
| $V_{B/R}$ | none | Ratio of basin volume to runoff volume |
| $V_{design}$ | ac-ft | Design volume of EDW, accounts for 20% basin filling with sediment |
| $V_P$ | ac-ft | Permanent pool design volume; taken as larger of $V_{P1}$ and $V_{P2}$ |
| $V_{P1}$ | ac-ft | Permanent pool volume calculated by method 1 |
| $V_{P2}$ | ac-ft | Permanent pool volume calculated by method 2 |
| $Vol_{FB}$ | ac-ft | Pre-sedimentation forebay volume |
| $Vol_{MP}$ | ac-ft | Micropool volume |
| WQv | ac-ft | Water quality volume |
| $W_v$ | ft | V-notch weir top width |
| $Z_{FB}$ | ft | Forebay depth |
| $Z_{MP}$ | ft | Micropool depth |
| $Z_{WQ}$ | ft | Depth of WQv above invert of outlet |



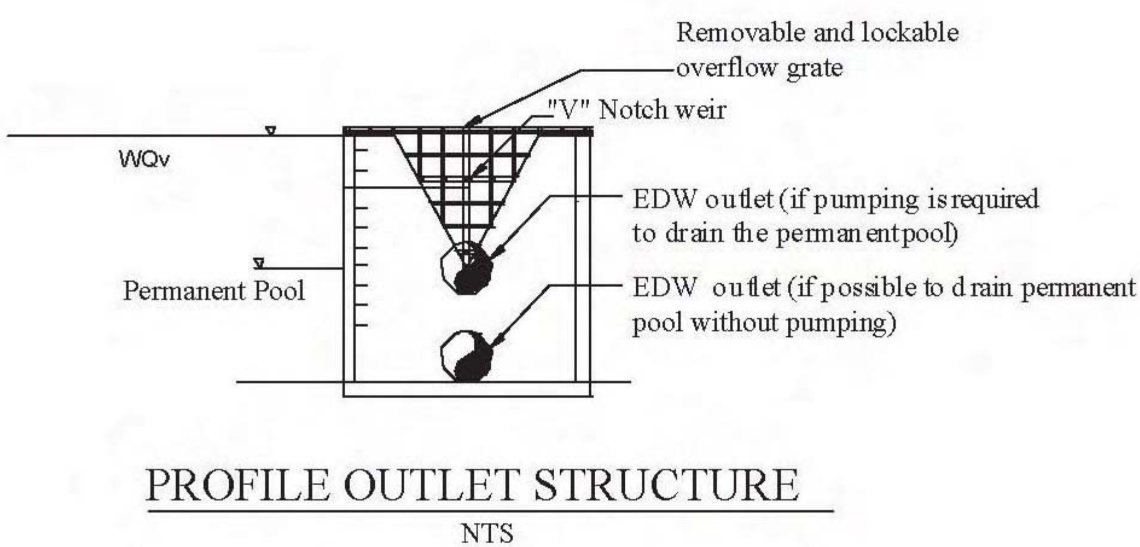
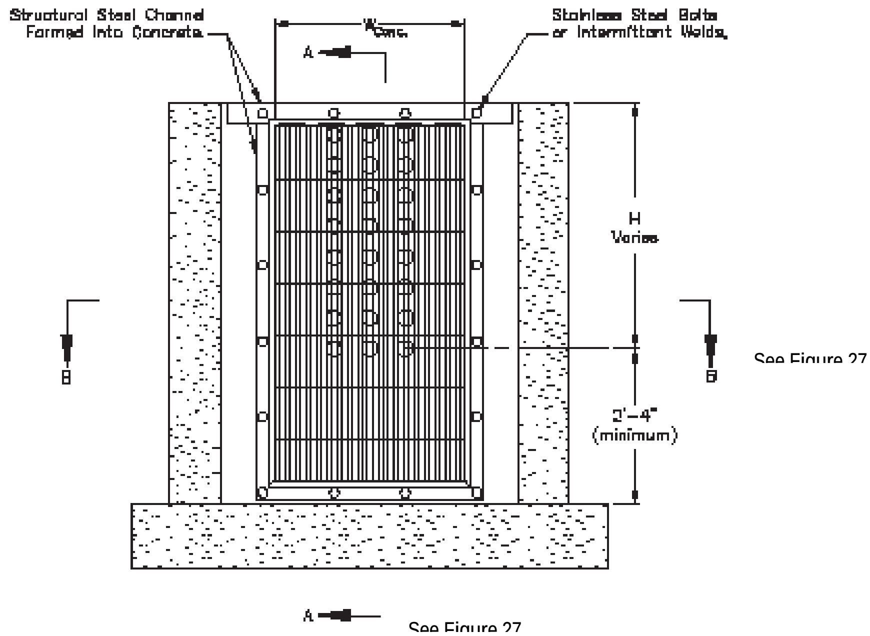




Figure 8.7 - "V" Notch Weir Outlet Structure




Elevation

WQv Trash Racks:

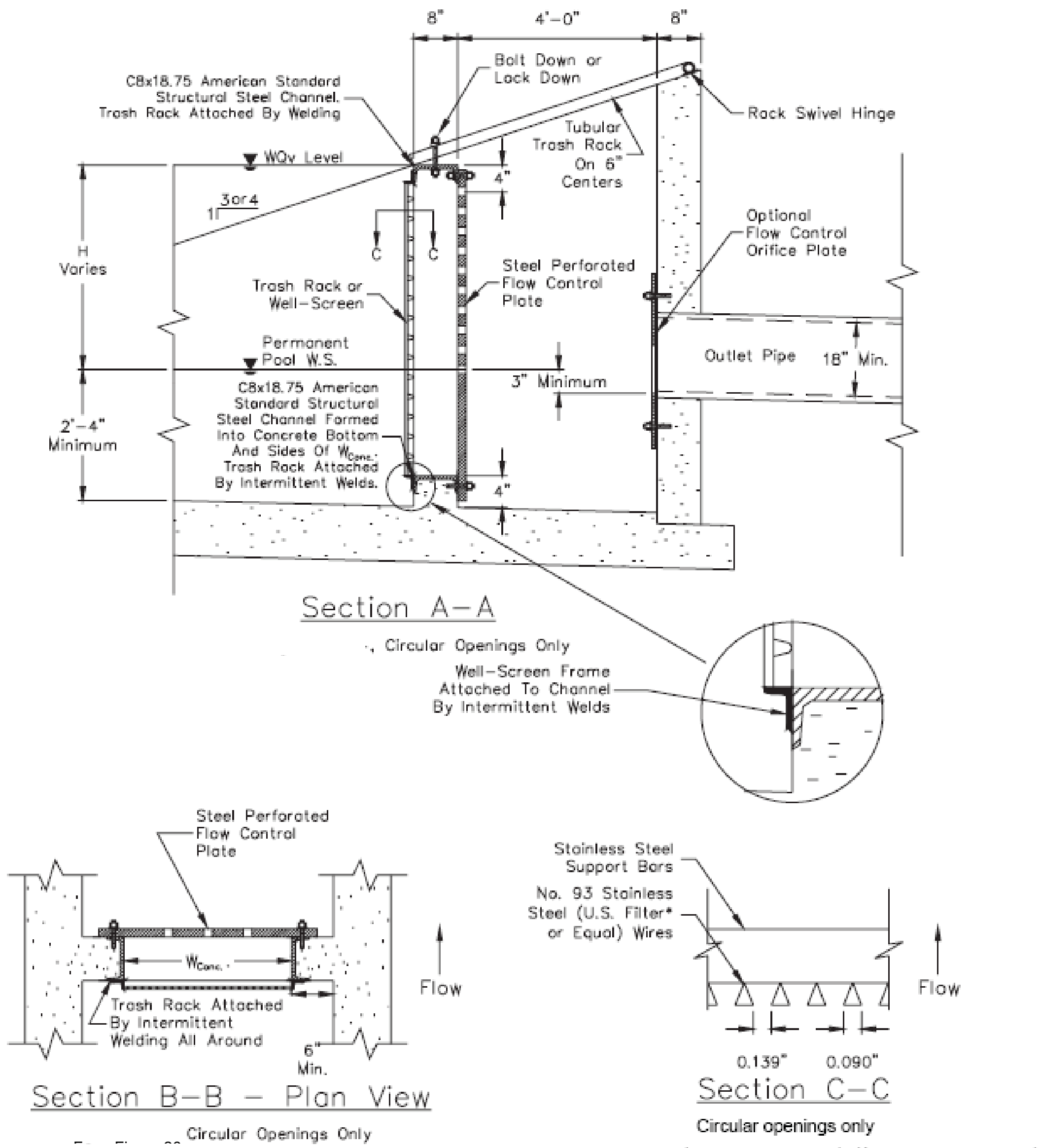
1. Well-screen trash racks shall be stainless steel and shall be attached by intermittent welds along the edge of the mounting frame.
2. Bar grate trash racks shall be aluminum and shall be bolted using stainless steel hardware.
3. Trash Rack widths are for specified trash rack material. Finer well-screen or mesh size than specified is acceptable, however, trash rack dimensions need to be adjusted for materials having a different open area/gross area ratio (R value)
4. Structural design of trash rack shall be based on full hydrostatic head with zero head downstream of the rack.

Overflow Trash Racks:

1. All trash racks shall be mounted using stainless steel hardware and provided with hinged and lockable or boltable access panels.
2. Trash racks shall be stainless steel, aluminum, or steel. Steel trash racks shall be hot dip galvanized and may be hot powder painted after galvanizing.
3. Trash Racks shall be designed such that the diagonal dimension of each opening is smaller than the diameter of the outlet pipe.
4. Structural design of trash rack shall be based on full hydrostatic head with zero head downstream of the rack.

Adapted from Denver Urban Drainage and Flood Control District

Figure 8.8 - WQv Outlet Orifice Plate and Trash Rack Design




Limits for this Standardized Design:

1. All outlet plate openings are circular.
2. Maximum diameter of opening = 2 inches.

*U.S. Filter, St. Paul, Minnesota, USA

R Value = (net open area)/(gross rack area) = 0.60

Adapted from Denver Urban Drainage and Flood Control District

Figure 8.9 - WQv Outlet Trash Rack Design

## 8.7 SAND FILTER

**Pocket Sand Filter Plan and Profile Example (for informational purposes only)**

Source: King County, Washington- www.metrokc.org

**Targeted Constituents**

| | |
|---|---|
| Sediment | ● |
| Nutrients | ◐ |
| Trash | ● |
| Metals | ◐ |
| Bacteria | ● |
| Oil and Grease | ● |
| Organics | ● |

Legend (Removal Effectiveness)

| High | Medium | Low |
|---|---|---|
| ● | ◐ | ○ |

### 8.7.1 Description

Sand filters are defined as stormwater quality treatment practices in which runoff is diverted to a self-contained bed of sand, collected in underground pipes, and discharged into a stream, channel, or sewer system. A typical sand filter system consists of two or three chambers or basins. The first is the sedimentation chamber, which removes floatable and heavy sediments. The second is the filtration chamber, which removes additional pollutants by filtering the runoff through a sand bed. The third is the discharge chamber. The treated filtrate normally is discharged through an underdrain system either to a storm drainage system or directly to surface waters. Sand filters take up little space and can be used on highly developed sites and sites with steep slopes. They can be added to retrofit existing sites. Sand filters can achieve high removal efficiencies for sediment, biological oxygen demand (BOD), and fecal coliform bacteria. Their ability to remove metals is moderate, and their ability to remove nutrients is often low.

### 8.7.2 General Application

Sand filters are intended primarily for water quality enhancement. In general, they are preferred over infiltration practices (such as infiltration trenches) when contamination of groundwater with conventional pollutants-BOD, suspended solids, and fecal coliform-is a concern. This usually occurs in areas where underlying soils alone cannot treat runoff adequately or where groundwater tables are high. Most sand filters can be constructed with impermeable basins or chamber bottoms, which help to collect, treat, and release runoff either to a storm drainage system or directly to surface water; this avoids contact between contaminated runoff and groundwater.

Sand filters are only feasible for highly impervious stabilized areas such as parking lots and rooftops. Sand for the filters should conform to AASHTO M-6 or ASTM C-33 ranging in size from 0.02 to 0.04 inch. Different configurations of sand filters are suitable for different types of sites depending on site conditions such as available space and type of development. The basic principles of all configurations are similar. Sand filter configurations include surface, underground, perimeter, and pocket. Each configuration is described in more detail below.

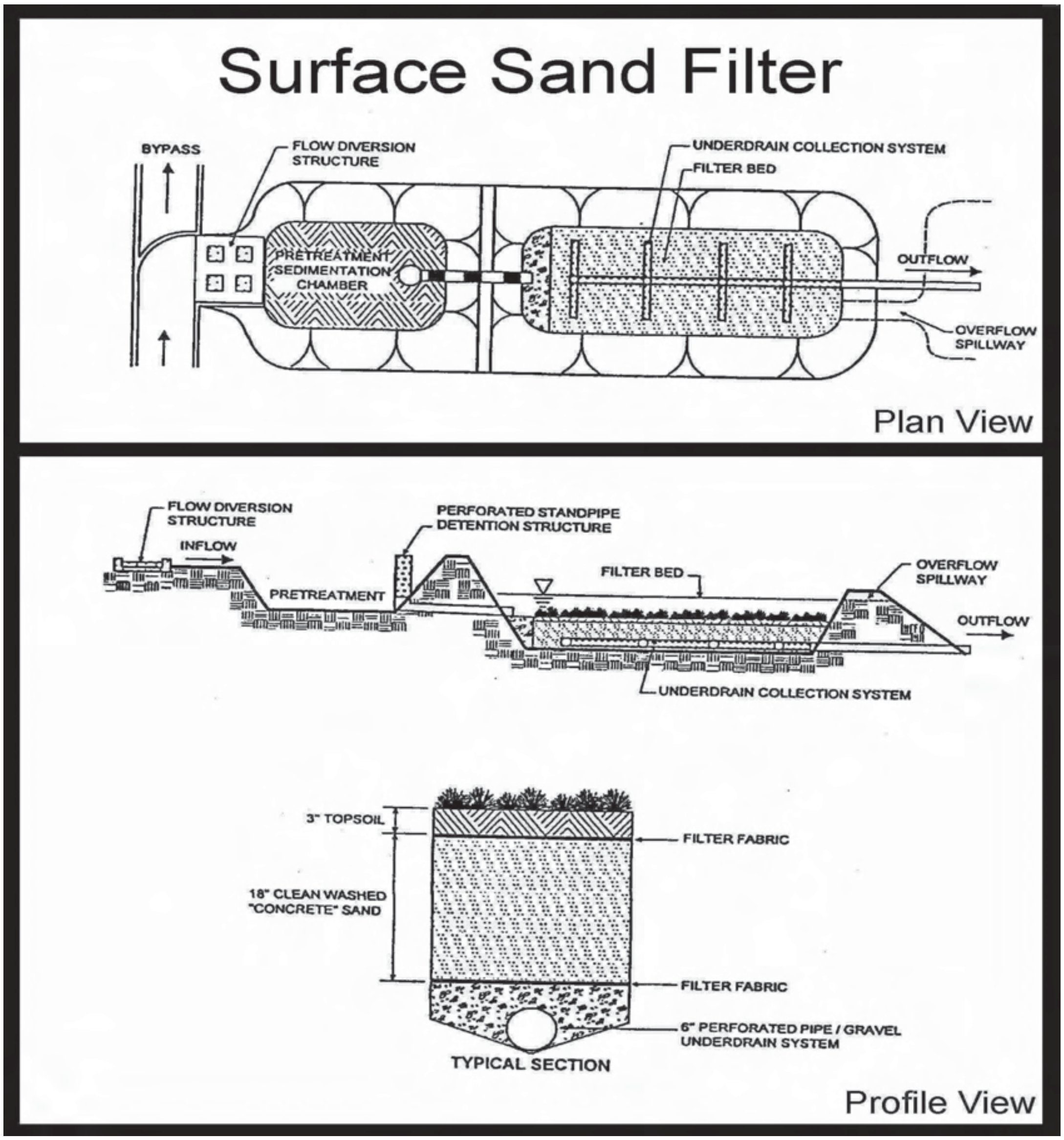
Surface sand filters (sometimes referred to as Austin sand filters) use an off-line sediment chamber to collect the first flush of stormwater; larger flows are diverted around the sedimentation chamber. Stormwater that is diverted into the sediment chamber is freed of coarse sediments. The water then flows from the sedimentation chamber into a depressional sand filter. The depressional area typically contains 18 inches of sand. The surface may be sand or preferably vegetation. Ponded water in the depressional area infiltrates through the sand and is collected in an underdrain that conveys the treated water to the stream or channel at a downstream point. Calculate sizing of a surface sand filter assuming a porosity of 40 percent for the sand and gravel, a coefficient of permeability of 3.5 feet per day for the sand, and an appropriate sediment basin to reduce the chances of clogging. Size the sedimentation basin based on the fall velocity of the smallest particle that the basin should capture (usually sand). The fall velocities for various sized particles are in ASCE, Manuals and Reports on Engineering Practice, No. 54, Sedimentation Engineering. If the surface of the sand filter is vegetated, be sure to specify a species that will not impede infiltration. Surface sand filters are best suited for treating parking lot and roof runoff where space is not limited. Typically, the surface sand filter system is designed to handle runoff from drainage areas up to 50 acres. Pretreatment is essential to the success of a surface sand filter. Figure 8.10 illustrates a typical surface sand filter.

Underground sand filters (also called Washington D.C. sand filters) use a three-chamber concrete vault placed at or beneath grade with the existing ground surface. The first chamber of the vault is used for pretreatment. It serves to settle coarse sediments and skim oil and floatable debris. The second chamber contains 18 inches of sand. Gravel, a protective screen, or permeable geotextile prevents clogging of the sand filter. Flow from the sand filter is collected in an underdrain and conveyed to the third chamber. The third chamber acts as a collection point for the stormwater. It fills and conveys the filtered stormwater through pipes to the stream or channel downstream. Provide access manholes of 30-inch minimum diameter for each chamber of the vault to allow cleaning. Typically, the underground sand filter system can handle runoff from completely impervious drainage areas of 1 acre or less. The sand filter system can accept the first 0.5 inch of runoff. Underground sand filters are ideal for retrofit situations where surface area is limited. Figure 8.11 illustrates a typical underground sand filter.

Perimeter sand filters use a two-chamber concrete vault. A typical application is along the perimeter of a parking lot. The first chamber of the vault is used for pretreatment that settles out coarse sediments. Stormwater flows over a weir into the second chamber that contains an 18-inch layer of sand. An underdrain system collects the filtered stormwater and conveys it to the stream or channel downstream. Provide access manholes for each chamber of the vault. Perimeter sand filters are best suited for parking lots and rooftops where surface area is limited.

Pocket sand filters (also called Delaware sand filters) are simplified surface sand filters only applicable to small sites. Stormwater must be pretreated by a sediment basin, filter strip, or other means before entering a pocket sand filter. The pocket sand filter consists of an excavated, shallow, depressional area. The depressional area contains the 18-inch layer of sand covered by a 3- to 4-inch soil layer that is vegetated. Typically, pocket sand filters are constructed where surrounding soils have a permeability of 0.5 to 2 inches per hour to allow the filtered water to infiltrate into surrounding soils. Be sure to specify a species of vegetation for pocket filters that will survive frequent periods of ponding and drought but will not impede infiltration. Typical pocket sand filter systems can handle runoff from drainage areas of 5 acres or less. A major advantage of the pocket sand filter is its shallow structure depth of only 30 inches, which reduces construction and maintenance costs. Figure 8.12 illustrates a typical pocket sand filter.

According to estimates, surface (Austin) sand filters, underground (Washington D.C.) sand filters, and pocket (Delaware) sand filters have the potential to remove 85 percent of suspended solids, 55 percent of phosphorous, 35 percent of nitrogen, and between 35 and 90 percent of metals from the stormwater (Claytor and Schueler 1996). Perimeter sand filters are estimated to remove 80 percent of suspended solids, 65 percent of phosphorous, and 45 percent of nitrogen.




***Source***: CWP 1996

Figure 8.10 - Surface Sand Filter Plan and Profile Example
(for informational purposes only)

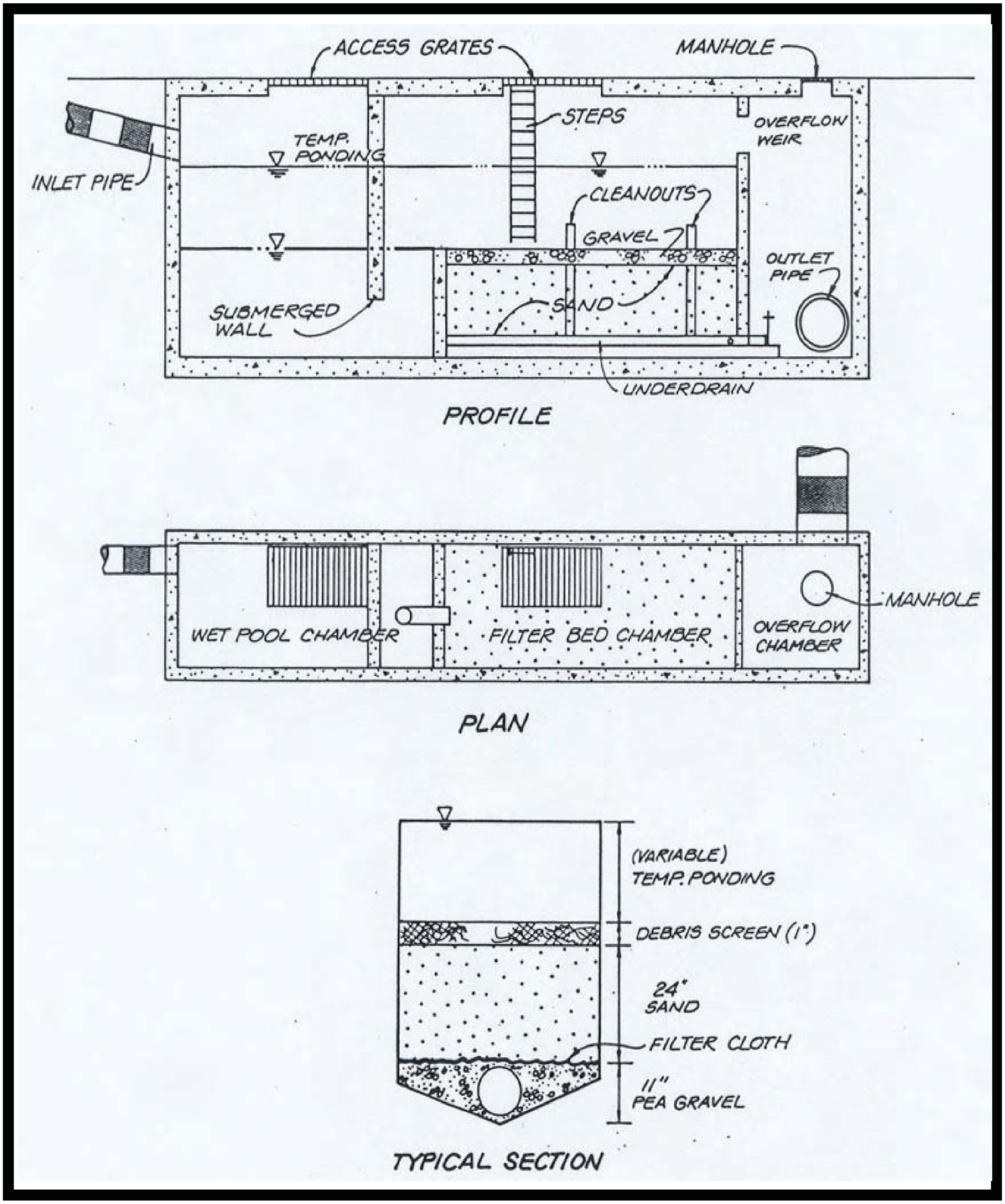



Figure 8.11 - Underground Sand Filter Plan and Profile Example
(for informational purposes only)

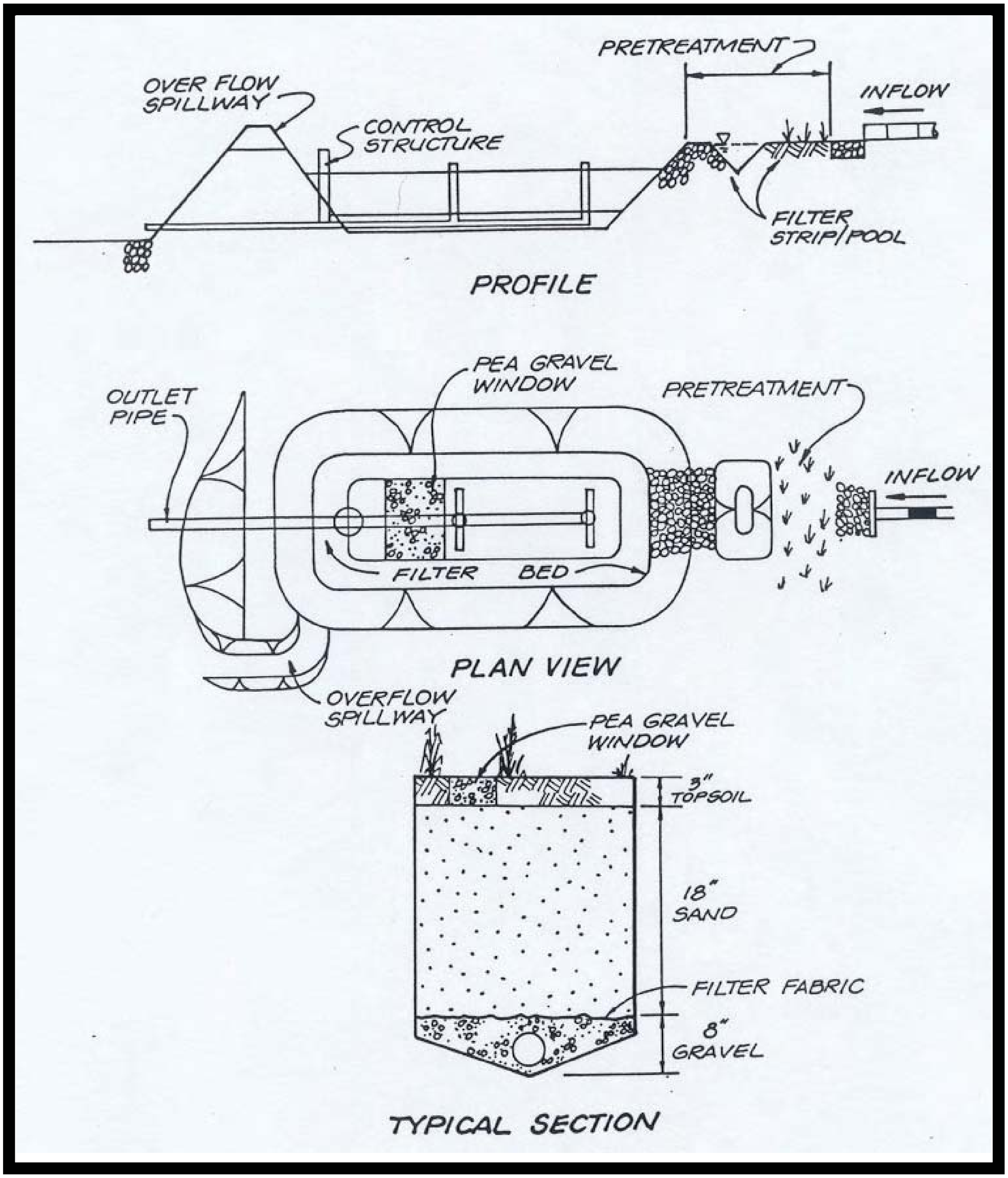



FIGURE 8.12 - Pocket Sand Filter Plan and Profile Example
(for informational purposes only)

### 8.7.3 Advantages

- Can effectively treat hot-spot runoff
- Consume small amounts of land (underground and perimeter sand filters)
- Improve water quality

### 8.7.4 Disadvantages

- OSHA-confined space for underground and perimeter sand filters
- Do not add aesthetic value

### 8.7.5 Design Requirements and Considerations

Restrict the contributing drainage to any sand filter to 5 acres or less. Design sand filters as off-line practices to capture and treat only the water quality storm and bypass all other storms. A flow regulation structure or flow splitter may be required along with the sand filter. Design a sedimentation basin in conjunction with all sand filters. Porosity (n) for sand and gravel should be 0.4 for sizing sand filters.

Determine the size of the sand filter bed surface area using Darcy's law:

$$A_f = WQv * d_f / [k * t_f (h_f + d_f)]$$

Where

$A_f$ = Surface area of the sand filter (square feet)

$d_f$ = Sand filter depth (feet)

k =
Coefficient of permeability for sand bed (feet per day)

$h_f$ = Average height of water above the sand bed (feet; hf = ½ * $h_{max}$, not to exceed 6 feet)

$t_f$ = Time required for the WQv to filter through the sand bed (days; 40 hours is recommended)

Compute the minimum required storage within the sand filter as follows:

$$V_{min} = 3/4 * WQv$$

Compute the water volume within the filter bed using the following equation:

$$Vf = Af * df * n$$

Where

n = porosity

For surface sand filters, compute the temporary water storage volume above the filter bed, $V_{f\text{-}temp}$.

Calculate the remaining volume required for the settling basin, $V_s$. $V_s$ should be approximately 50 percent of $V_{min;}$ adjustments of $h_f$ may be required to meet this criterion. $V_s$ can be calculated as follows:

$$V_s = V_{min} - (V_f + V_{f\text{-}temp})$$

Where

$V_{f\text{-}temp}$ = Temporary storage volume in the filter media

Calculate the height in the settling basin, $h_s$:

$h_s = V_s / A_s$

Where

$A_s$ = Surface area of the BMP

Verify that $h_s > 2 * h_f$, and $h_s$ equals or exceeds 3 feet. If not, adjust $h_f$ and repeat the sizing procedure.

For underground sand filters, compute the minimum wet pool volume in the settling basin, $V_w$. As a minimum, $V_w = A_s * 3$.

Calculate the temporary storage volume required in both chambers:

$V_{temp} = V_{min} – (V_f + V_w)$

Compute the total surface area of both chambers, $A_t$:

$A_t = A_f + A_s$

Calculate the additional temporary storage height, $h_{add}$, using the following equation:

$h_{add} = V_{temp} / A_t$

Ensure that $h_{add}$ equals or exceeds $2 * h_f$. Adjustments to $h_f$ may be necessary to meet this requirement.

For perimeter sand filters, compute the minimum wet pool volume in the settling basin, $V_w$. As a minimum, $V_w = A_s * 2$.

Calculate the temporary storage volume required in both chambers:

$V_{temp} = V_{min} – (V_f + V_w)$

Compute the total surface area of both chambers, $A_t$:

$A_t = A_s + A_f$

Calculate the additional temporary storage height, $H_{temp}$, using the following equation:

$h_{temp} = V_{temp} / A_t$

Ensure that $h_{temp}$ equals or exceeds $2 * h_f$. Adjustments to $h_f$ may be necessary to meet this requirement.

For pocket sand filters, compute the temporary water storage volume above the filter bed, $V_{temp}$:

$V_{temp} = V_{min} - V_f$

Calculate the temporary storage height in the settling basin, $h_{temp}$:

$H_{temp} = V_{temp} / A_{avg}$, where $A_{avg}$ is the average area of the pocket sand filter.

Set the emergency spillway elevation of the pocket sand filter at $h_{temp}$.

### 8.7.6 Maintenance and Inspections

The following is a partial list of maintenance issues related to sand filters:

- Inspect for erosion of pretreatment surface and pocket sand filters biannually
- Monitor the water level in underground sand filters quarterly

- Frequently inspect the overflow systems
- Frequently remove organic material from the site
- Frequently inspect and mow vegetation (keep less than 18 inches)
- Frequently remove sediment in the sediment basin or chamber
- Inspect structural components for degradation regularly

### 8.7.7 Design Example

To be completed at a later date.

## 8.8 WETLAND SWALES

Source: Olsson Associates

**Targeted Constituents**

| | |
|---|---|
| Sediment | ● |
| Nutrients | ◐ |
| Trash | ◐ |
| Metals | ◐ |
| Bacteria | ◐ |
| Oil and Grease | ● |
| Organics | ● |

Legend (Removal Effectiveness)

| High | Medium | Low |
|---|---|---|
| ● | ◐ | ○ |

### 8.8.1 Description

Wetland Swales are broad, shallow, natural, or constructed channels with a dense stand of native vegetation covering the side slopes and emergent vegetation covering the channel bottom. Unlike a Bio-Swale, a Wetland Swale does not include a prepared soil filter bed or underdrain system. They slowly convey stormwater runoff, and in the process promote infiltration, plant transpiration, adsorption, settling of suspended solids, and microbial breakdown of pollutants. Wetland Swales essentially act as a very long and linear shallow Wetland treatment system.

### 8.8.2 General Application

Wetland Swales can serve as part of a Stormwater drainage system and can replace curbs, gutters, and storm sewer systems. Figure 8.13 illustrates a typical Wetland Swale. The feasibility of installing a Wetland Swale at a particular site depends on the area and slope of the contributing watershed. Wetland Swales can be used where the water table is at or near the surface or where there is a sufficient water balance in poorly drained soils to support a Wetland plant community. Wetland Swales are well suited for roadside applications or along the property boundaries of residential developments. The water quality volume for high density commercial and industrial land uses will most likely be too great to be accommodated with most Swale designs. However, Wetland Swales may be appropriate for pretreatment with other practices for these higher density land uses.

The tributary area should be stabilized before construction of a Wetland Swale. During construction, minimize disturbance to the underlying soil bed. A pre-treatment forebay may be required for sites expecting high levels of suspended sediment to prevent premature clogging. Energy dissipation is needed at the inlet for all Wetland Swales that receive piped flow. Select grass and plant species that tolerate low maintenance and can survive without significant human influence (see Appendix A).

### 8.8.3 Advantages

- Constructed less expensively and maintained more easily than underground pipes
- Well suited to sites with relatively little slope
- Improve water quality by sedimentation and biological uptake

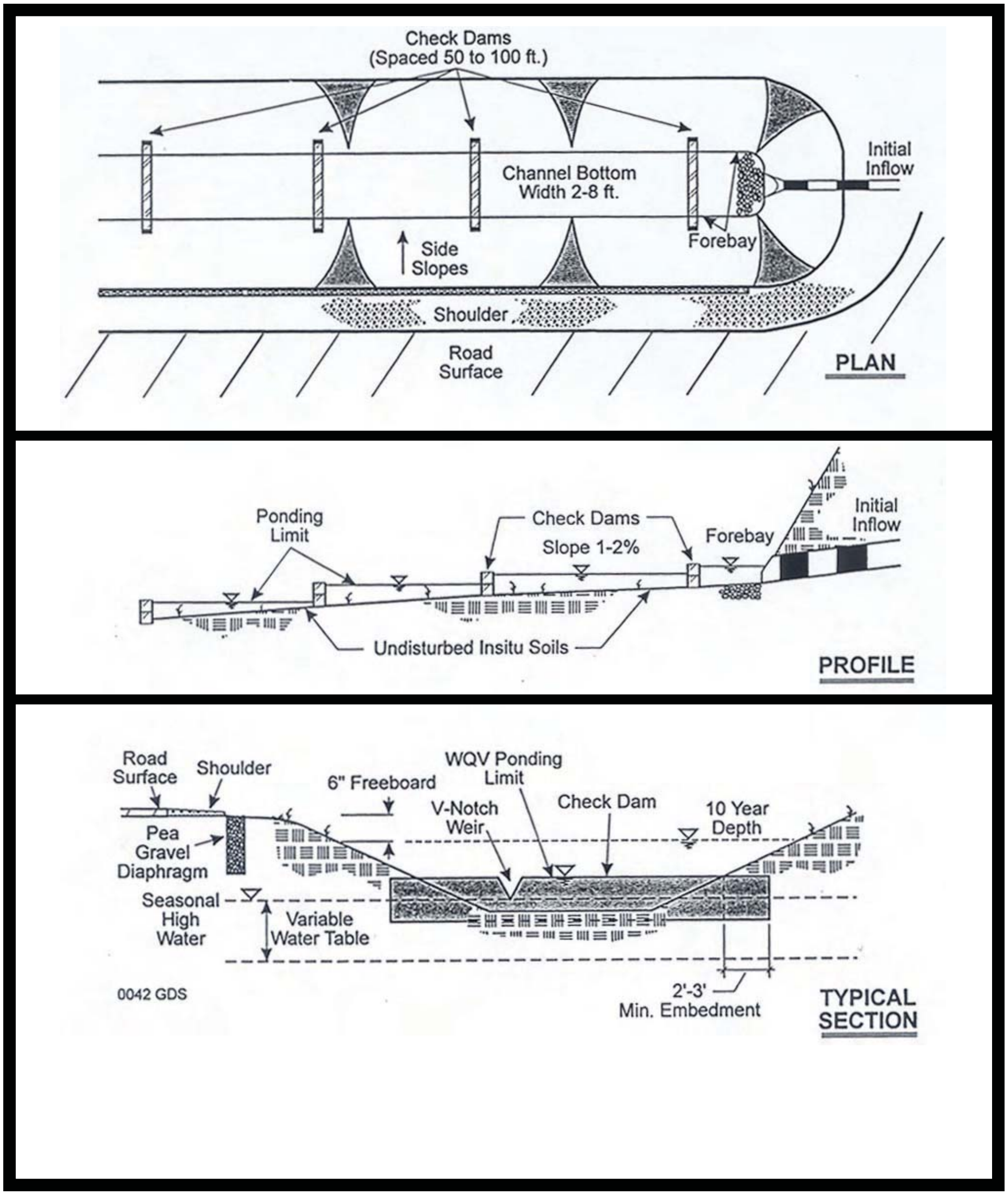



FIGURE 8.13 - Wetland Swale Plan and Profile Example
(for informational purposes only)

- Reduce total volume of runoff to surrounding streams and rivers
- Minimize erosion by slowing the conveyance of water
- Enhance biological diversity and create beneficial habitat between upland and surface waters.

### 8.8.4 Disadvantages

- May not be feasible to implement after development has occurred
- Impractical in areas with steep topography
- Area requirements can be excessive for highly developed sites
- May erode when flow volumes and/or velocities are high during storm events
- Not designed to be the fastest conveyance method and, therefore, require exact placement and design to minimize risk of flooding
- May attract mosquito and other nuisance vectors (See Section 8.12)
- Becomes less feasible along roadsides as the number of driveway entrances requiring culvers increase

### 8.8.5 Design Requirements and Considerations

The detention/retention capacity of a Wetland Swale is governed by the runoff associated with the "water quality storm." This design approach for sizing Wetland Swales is based on temporarily storing the WQV within a shallow ponding area for a period of 24 hours. This methodology incorporates volume based sizing criteria for the WQV, and a rate based criteria for checking the erosive potential during the 50% storm event. If the Wetland Swale is intended to convey flow in excess of the 50% storm event consult local ordinances for design criteria. Do not use Wetland Swales as a BMP component to convey deep concentrated flow.

The following design specifications are summarized in Table 8.5.

#### *8.8.5.1 Shape and Slope*

- The Swales should generally be trapezoidal in shape, although a parabolic shape is also acceptable (provided the width is equal to or greater than the design bottom width for a trapezoidal cross section). The criteria presented in this section assume a trapezoidal cross section.
- For the trapezoidal cross section, size the bottom width between 2 and 8 feet. The 2-foot minimum allows for construction considerations and ensures a minimum filtering surface for water quality treatment. The 8-foot maximum reduces the likelihood of flow channelization within a portion of the Swale. Widths up to 16 feet may be used if separated by a dividing berm or structure to avoid braiding.
- The side slopes of the channel should be no steeper than 3:1 for maintenance and safety considerations. Flatter slopes are encouraged where adequate space is available to aid in providing pretreatment for lateral flows.
- A longitudinal slope less than 2% is recommended. When natural topography necessitates, steeper slopes may be acceptable if check dams (vertical drops of 6 to 12 inches) are used. These structures will require additional energy dissipating measures and should be placed no closer than 50 to 100 foot interval. V-notched weirs in the check dams can be utilized to direct flow and volumes.

TABLE 8.5
Design Summary for Wetland Swales

| Parameter | Swale Design Criteria |
|---|---|
| Energy Dissipation | Required if piped inflow |
| Pretreatment | Use forebay if high sediment load expected |
| Bottom Width | 2 feet minimum, 8 feet maximum, widths up to 16 feet are allowable if a dividing berm or structure is used |
| Side Slopes | 3:1 or flatter preferred |
| Longitudinal Slope | Up to 2% without check dams |
| Underlying soil bed | Undisturbed soils equal to the Swale width No underdrain system |
| Drainage Area | 5 acres or less |
| Sizing Criteria | Length, depth, width, and slope necessary to provide surface storage for WQv. Outlet structures sized to release WQv over 24 hours. |
| Depth and Capacity | Surface storage of WQV with a maximum depth of 18 inches for water quality treatment (12" average depth)<br>Safely convey the 50% event with non-erosive velocity (< 4 fps).<br>Consult local design criteria for flows greater than the 50% storm event. |

### *8.8.5.2 Design Size and Soils*

***Source***: Metropolitan Council of Environmental Services. 2001 Minnesota Urban Small Sites BMP Manual, St. Paul, MN.

Wetland Swales should have a contributing drainage area of 5 acres or less.

- The Swale length, width, depth, and slope should be designed to temporarily accommodate the WQv through surface ponding. The WQv must be retained for 24 hours but ponding may occur indefinitely depending on the depth and elevation of the water table.
- Design Swales to provide a shallow ponding depth for the WQv (a maximum of 18 inches - average depth 12 inches).
- Calculate the velocity and depth of flow through the Swale using the 50% design flow rate. Maximum flow velocity shall not exceed 4 fps and the maximum flow depth shall not exceed 2 ft at the 50% design flow rate. If these conditions are not attained, modify Swale geometry, each time altering the depth, bottom width or longitudinal slopes until these criteria are satisfied.
- Provide bypass for high flows if the Swale cannot be stable during the 10% or greater storm event.
- Check permissible velocities of soil and of selected vegetation to ensure the 50% storm event is non-erosive.

* Compute WQv drawdown time to ensure that it is 24 hours.
* The WQv for high density residential, commercial, and industrial land uses may be too great to be accommodated with most Swale designs. If the WQv is too great to be accommodated with Swale design, additional off-line storage may be incorporated (See Figure 8.14). In addition, Wetland Swales may be appropriate in association with other practices for these higher density land uses.

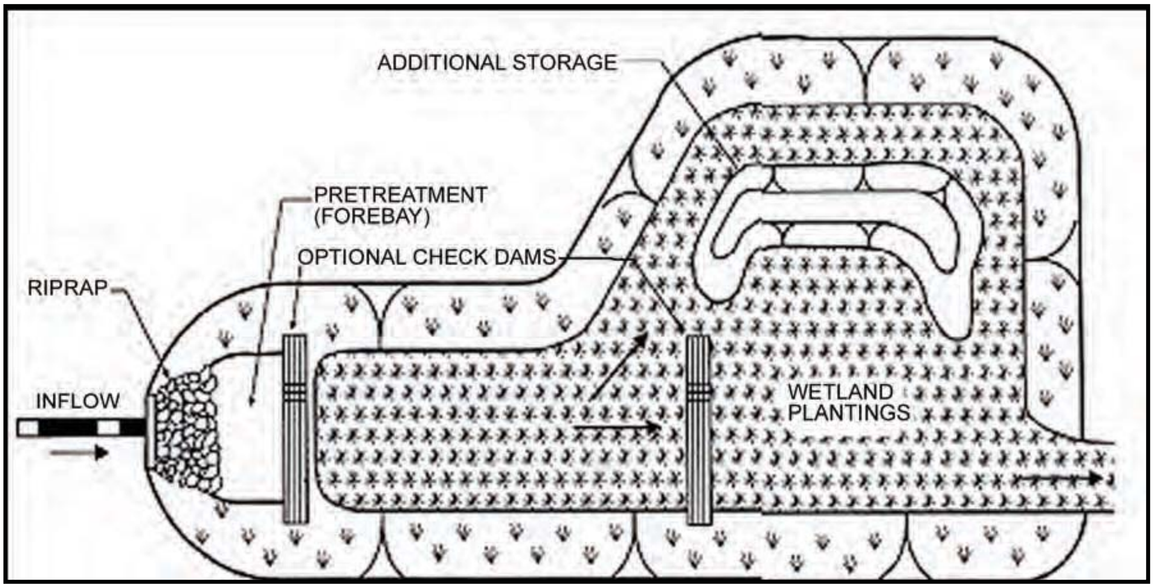


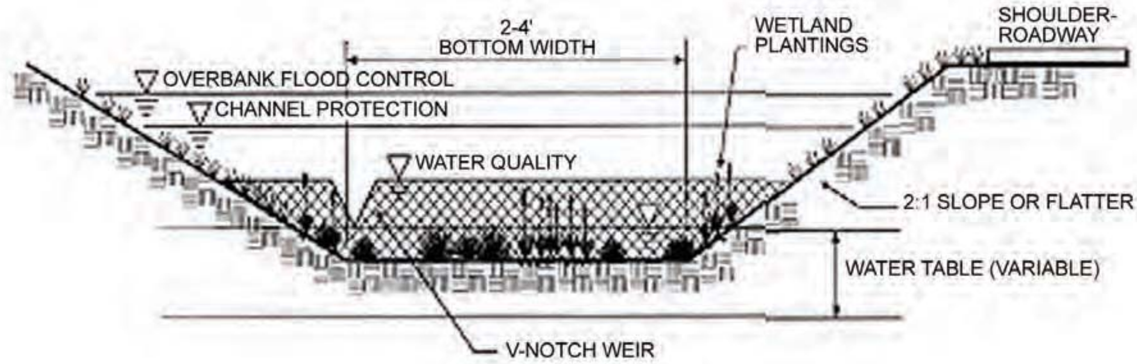

FIGURE 8.14 - Wetland Swale
(source: Minnesota Urban Small Sites BMP Manual)

* See that the soil bed below the Swale consists of undisturbed soils. This area may be periodically inundated and remain wet for long periods of time.
* Do no construct wet Swales in gravelly and coarse sandy soils that cannot easily support dense vegetation.
* Use outlet protection at any discharge point from Wetland Swales to prevent scour at the outlet.
* If the heavy sediment loading at a site is a concern provide pretreatment to protect the filtering and infiltration capacity of the Swale bed. Pretreatment can occur in a sediment forebay behind a check dam with a pipe inlet.

#### *8.8.5.3 Vegetative Cover*

***Source***: Metropolitan Council Environmental Services. 2001 *Minnesota Urban Small Sites BMP Manual,* St. Paul, MN.

* Species selection will depend upon the duration of water inundation, soil type, and amount of light. Desirable vegetative characteristics include species that form dense sod with vigorous, upright growth. Species that have tendencies to mat down should not be used when sediment filtering is the desired outcome.




*Source: Center for Watershed Protection. 2001*

FIGURE 8.15 - Typical Wetland Swale Cross Section

- Specify plant species resistant to periodic inundation and periodic drought. Specify vegetation required to meet design condition (see Appendix A).
- Appropriate soil stabilization methods, such as mulch, blankets or mats should be used before the establishment of vegetation. Seeding, sodding, and other items related to establishing vegetation should be in accordance with accepted erosion-control and planning practices.

### 8.8.6 Maintenance and Inspections

***Source***: Metropolitan Council Environmental Services. 2001 *Minnesota Urban Small Sites BMP Manual,* St. Paul, MN.

The following is a partial list of actions to maintain Wetland Swales:

- Inspect Swale several times the first few months to ensure plant species are establishing well. If not, reseed or plant an alternative species. Also, inspect the channel for erosion after every rainfall event and repair as necessary.
- If a forebay is used, inspect and remove excessive sediment, trash, and debris and dispose of in an appropriate location.
- Control vegetation by mowing or grubbing techniques (not by chemicals).
- If heavy sediment loading occurs, clean the channel to remove excess material.

### 8.8.7 Design Example

To be completed at a later date.

## 8.9 BIOSWALES

Source: Georgia Stormwater Manual

**Targeted Constituents**

| | |
|---|---|
| Sediment | ● |
| Nutrients | ◐ |
| Trash | ○ |
| Metals | ◐ |
| Bacteria | ◐ |
| Oil and Grease | ◐ |
| Organics | ◐ |

Legend (Removal Effectiveness)

| High | Medium | Low |
|---|---|---|
| ● | ◐ | ○ |

### 8.9.1 Description

Bio-Swales are broad, shallow, natural, or constructed channels with a dense stand of vegetation covering the side slopes and channel bottom. They slowly convey stormwater runoff, and in the process promote infiltration, reduce flow velocities, and pretreat stormwater. Bio-Swales can have either parabolic or trapezoidal cross sections. Bio-Swales include an engineered soil matrix and an under-drain system for drainage.

### 8.9.2 General Application

Rather than routing stormwater runoff into a lined channel or into a curb-gutter system, consider using a natural conveyance channel. Bio-Swales promote infiltration, filter pollutants through an engineered media and through plant biological uptake. Do not use channels as a BMP component to convey deep concentrated flow; channels are only effective conveying shallow concentrated flow. Take care to identify the proper location for a Bio-Swale. Minimizing disturbance to the area (for example, avoiding application of pesticides and herbicides) maintains the channel's ability to remove contaminants. Select grass and plant species that tolerate low maintenance and can survive without significant human influence (see Appendix A).

### 8.9.3 Advantages

- Constructed less expensively and maintained more easily than underground pipes
- Underdrain system allows swale to remain dry most of the time and are desirable in residential settings.
- Improve water quality primarily by filtration through an engineered media. Pollutants are also removed through biological uptake.
- Reduce total volume of excess urban runoff to surrounding streams and rivers
- Minimize stream erosion by slowing the conveyance of water
- Enhance biological diversity and create beneficial habitat between upland and surface waters.

### 8.9.4 Disadvantages

- May not be feasible to implement after development has occurred
- Area requirements can be excessive for high-density development sites

- Not designed to be the fastest conveyance method and, therefore, require exact placement and design to minimize risk of flooding

### 8.9.5 Design Requirements and Considerations

To maximize pollutant removal efficiency, the time runoff is in contact with the vegetated swale should be maximized, and channelization of high flows should be avoided. This methodology is designed to treat the WQv through a volume-based design. If the wetland Swale is intended to convey flood flows in excess of the WQv, consult local ordinances for design criteria and freeboard requirements.

#### *8.9.5.1 Shape and Slope*

- The swales should generally be trapezoidal in shape, although a parabolic shape is also acceptable (provided the width is equal to or greater than the design bottom width for a trapezoidal cross section). The criteria presented in this section assume a trapezoidal cross section. Figure 8.16 below illustrates a typical Bio-Swale section.
- For the trapezoidal cross section, size the bottom width between 2 and 8 feet. The 2-foot minimum allows for construction considerations and ensures a minimum filtering surface for water quality treatment. The 8-foot maximum reduces the likelihood of flow channelization within a portion of the swale.
- The side slopes of the channel should be no steeper than 3:1 for maintenance and safety considerations. Flatter slopes are encouraged where adequate space is available to aid in providing pretreatment for lateral flows.

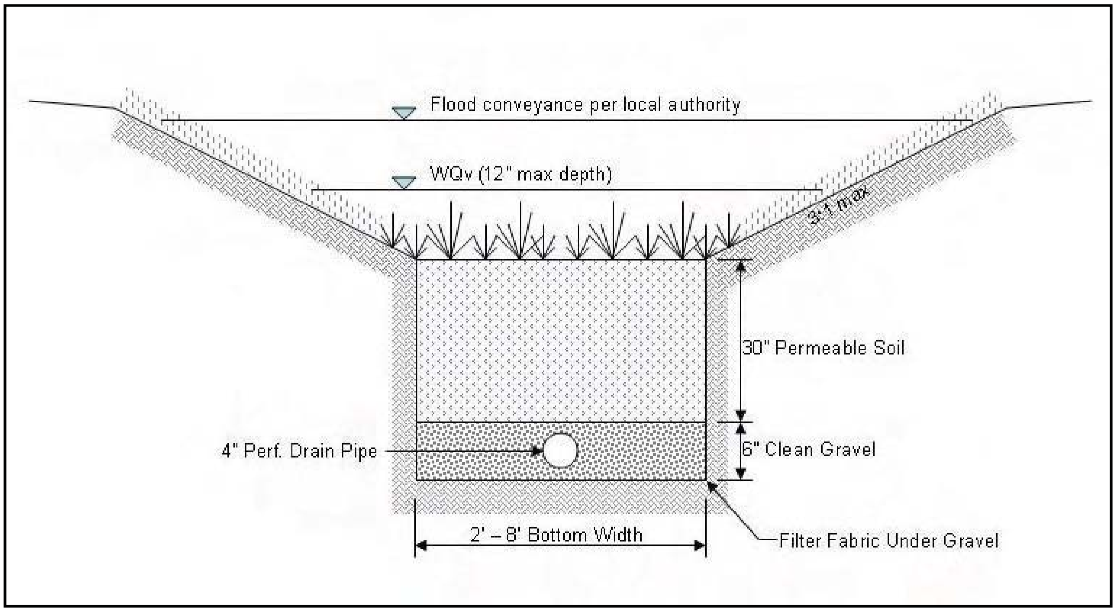



Figure 8.16 - Typical Bioswale Section

- Longitudinal slope between 1%-4% is recommended. When natural topography necessitates, steeper slopes may be acceptable if rock check dams (vertical drops of 6 to 12 inches) are used. These structures will require additional energy dissipating measures and should be placed no closer than 50 to 100 foot interval.

TABLE 8.6
Design Summary for Bio Swales

| Parameter | Swale Design Criteria |
|---|---|
| Energy Dissipation | Required if piped inflow to swale |
| Pretreatment | Use forebay if high sediment load expected |
| Bottom Width | 2 feet minimum, 8 feet maximum |
| Side Slopes | 3:1 or flatter preferred |
| Longitudinal Slope | Up to 4% without check dams |
| Underlying soil bed | 6" gravel with perforated underdrain pipe under 30" permeable soil |
| Sizing Criteria | Bio-Swales shall be sized to store and infiltrate the entire water quality volume (WQv) with less than 12" of ponding at any point in the swale with a maximum ponding time of 40 hours. Additional conveyance capacity and freeboard provided per local authority. |
| Erosion Protection | Width and slope shall be designed to ensure velocity of less than 5 fps in the 50% (2-year) discharge. |

*8.9.5.2 Design Procedure*

- Compute the water quality runoff volume (WQv) and applicable flood conveyance discharges, as applicable per local criteria.
- Determine pretreatment volume. The forebay should be sized to contain 20% of the contributing WQv. The forebay storage volume counts toward the total WQv requirement and should be subtracted from the WQv for subsequent calculations.
- Determine Bio-Swale dimensions. Design swale to store and infiltrate the WQv with a maximum ponding depth of 12 inches and maximum ponding time of 40 hours. Design the bed of the swale to contain a permeable soil layer of at least 30 inches in depth, above a 4-inch diameter perforated PVC pipe (AASHTO M 252) longitudinal underdrain in a 6-inch gravel layer. The soil media should have an infiltration rate of at least 1 foot per day (1.5 feet per day maximum) and contain a high level of organic material to facilitate pollutant removal.
- Determine number of rock check dams necessary to store the WQv.
- Calculate the velocity and depth of flow through the swale using the 50% flow rate; maximum flow velocity shall not exceed 5.0 ft/s for erosion prevention. If these conditions are not attained, modify swale geometry, each time altering the depth, bottom width or longitudinal slopes until these criteria are satisfied.
- Provide bypass for high flows if the swale cannot be stable during the 10% or greater storm event.
- Check local criteria for flood conveyance and freeboard requirements.

- Use outlet protection at any discharge point from wetland swales to prevent scour at the outlet.
- The underdrain system should discharge to the storm drainage infrastructure or a stable outfall.

#### 8.9.5.3 *Vegetative Cover*

- Species selection will depend upon the duration of water inundation, soil type, and amount of light. Desirable vegetative characteristics include species that form dense sod with vigorous, upright growth.
- Specify plant species resistant to periodic inundation and periodic drought. Specify vegetation required to meet design condition (see Appendix A).
- Appropriate soil stabilization methods, such as mulch, blankets or mats should be used before the establishment of vegetation. Seeding, sodding, and other items related to establishing vegetation should be in accordance with accepted erosion-control and planning practices.

#### 8.9.5.4 *Maintenance and Inspections*

The following is a partial list of actions to upkeep Bio-Swales:

- Inspect swale several times the first few months to ensure plant species are establishing well. If not, reseed or plant an alternative species. Also, inspect the channel for erosion after every rainfall event and repair as necessary.
- If a forebay is used, inspect and remove excessive sediment, trash, and debris and dispose of in an appropriate location.
- Control vegetation by mowing or grubbing techniques (not by chemicals).
- If heavy sediment loading occurs, clean the channel to remove excess material.

## 8.10 EXTENDED WET DETENTION

Source: Tetra Tech, Inc.

**Targeted Constituents**

| | |
|---|---|
| Sediment | ● |
| Nutrients | ◐ |
| Trash | ● |
| Metals | ◐ |
| Bacteria | ◐ |
| Oil and Grease | ○ |
| Organics | ◐ |

Legend (Removal Effectiveness)

| High | Medium | Low |
|---|---|---|
| ● | ◐ | ○ |

### 8.10.1 Description

Extended wet detention basins (EWDBs) are designed to collect stormwater runoff in a permanent pool and a temporary water quality pool during storm events (Urban Drainage and Flood Control District, 2005). The primary removal mechanism is settling as stormwater runoff resides in this pool, but pollutant uptake, particularly of nutrients, also occurs to some degree through biological and chemical activity in the pond (California Stormwater Quality Association, 2003). In addition, a temporary detention volume is provided above this permanent pool to capture the water quality volume (WQv) and enhance sedimentation (Urban Drainage and Flood Control District, 2005).

EWDBs are similar to extended dry detention basins (EDDBs) because they are designed to capture runoff from frequently occurring storms. However, EWDBs differ from EDDBs because the influent water mixes with the permanent pool water as it rises above the permanent pool level. The surcharge captured volume above the permanent pool is then released over 40 hours (Urban Drainage and Flood Control District, 2005). EWDBs are also similar in function to constructed wetlands, and differ primarily in having a greater average depth (California Stormwater Quality Association, 2003).

EWDBs can be very effective in removing pollutants, and, under the proper conditions, can satisfy multiple objectives, including water quality improvement, flooding and erosion protection, creation of wildlife and aquatic habitats, and recreational and aesthetic provision (Urban Drainage and Flood Control District, 2005).

### 8.10.2 General Application

EWDBs can be used to improve stormwater runoff quality and reduce peak stormwater runoff rates and peak stages. An EWDB can be used to improve the quality of urban runoff from roads, parking lots, residential neighborhoods, commercial areas, and industrial sites, and is generally used to treat larger tributary areas than other best management practices (BMPs), or as follow-up treatment downstream of other BMPs. It can be used as an onsite BMP if the tributary area is sufficient to sustain a permanent pool. An EWDB works well in conjunction with other BMPs, such as upstream onsite source controls and downstream filter basins or wetland channels (Urban Drainage and Flood Control District, 2005). See treatment train Figure 3.3. An EWDB can also be designed to provide flood control benefits.

### 8.10.3 Advantages

- Because of the presence of the permanent wet pool, properly designed and maintained EWDBs can provide significant water quality improvement across a relatively broad spectrum of target constituents, including dissolved nutrients and many urban pollutants (California Stormwater Quality Association, 2003) (Urban Drainage and Flood Control District, 2005).
- Widespread application of EWDBs with sufficient capture volume and 40 hour water quality pool drawdown can provide significant control of channel erosion and enlargement caused by changes to flow frequency relationships resulting from the increase of impervious cover in a watershed (California Stormwater Quality Association, 2003).
- If properly designed, constructed, and maintained, EWDBs can provide substantial aesthetic/recreational value and wildlife and wetlands habitat (California Stormwater Quality Association, 2003).
- EWDBs can easily be designed to incorporate flood control volumes.
- EWDBs can be used for larger tributary areas.

### 8.10.4 Disadvantages

- The public can sometimes view EWDBs as a safety concern (California Stormwater Quality Association, 2003).
- Maintenance and sediment removal can be more difficult for EWDBs than it is for EDDBs because of the presence of the permanent pool. Possible additional maintenance concerns with an EWDB include floating litter, scum and algal blooms, nuisance odors, and aquatic plants blocking outlet works (Urban Drainage and Flood Control District, 2005).

- EWDBs require a permanent pool to function properly (California Stormwater Quality Association, 2003). These facilities may not be feasible in some locations because of insufficient tributary area to maintain the permanent pool.
- If not properly designed and maintained, the permanent pool may attract large numbers of geese, which can add to the nutrient and fecal coliform loads entering and leaving the facility (Urban Drainage and Flood Control District, 2005).
- In general, EWDBs can be more expensive and take more land than other BMPs (besides EDDBs).

### 8.10.5 Design Requirements and Considerations

The following guidelines are to be considered when designing EWDBs:

- EWDBs shall be designed as off-line facilities located outside of stream corridors and buffer areas to limit environmental impacts downstream when maintaining the facility.
- EWDBs shall have between 2 and 1,000 acres tributary to the facility (Kansas City Metropolitan Chapter of the American Public Works Administration, 2006).
- Design of the permanent pool volume should allow for 14 days hydraulic residence time to allow for particulate settling and nutrient uptake. This is accomplished by sizing the pool using regional precipitation data and characteristics of the tributary area to the EWDB. These considerations are illustrated in the design example at the end of this section (Metropolitan Nashville – Davidson County, 2000).
- The EWDB shall be designed to detain the WQv above the permanent pool. Additional flood control volume can also be provided above the permanent pool (Urban Drainage and Flood Control District, 2005). See APWA 5600 for design specifications if flood control is to be incorporated into the design of the EWDB.
- An impermeable liner may be required to maintain an adequate permanent pool level (California Stormwater Quality Association, 2003).
- The permanent pool shall include a littoral bench, or shelf, around the pool's perimeter. This bench serves as both a safety feature and a planting surface for wetland vegetation. The littoral bench shall extend inward at least 10 feet from the perimeter of the permanent pool and shall be between 6 inches to 12 inches below the permanent pool surface (California Stormwater Quality Association, 2003) (Urban Drainage and Flood Control District, 2005). The slope of the bench shall not exceed 6:1. The bench shall be planted with native wetland vegetation to promote biological uptake of nutrients and dissolved pollutants and reduce the formation of algal mats. To maximize biological uptake but prevent plants from encroaching on the open water surface, the vegetated littoral bench shall comprise 25 percent to 50 percent of the permanent pool surface area (Metropolitan Nashville – Davidson County, 2000).
- A sediment forebay shall be incorporated into the EWDB design to trap sediment and trash at all basin inlets, where the sediment and trash can be more easily removed than from the permanent pool (Kansas City Metropolitan Chapter of the American Public Works Administration, 2006). The forebay shall be at least 10 percent of the WQv and shall be 4 to 6 feet deep. These design criteria allow the forebay to function for longer periods between required sediment removal, possibly for up to 5 years. The use of a sediment forebay can extend the sediment removal interval from the permanent pool by 150 percent (Naval Facilities Engineering Service Center, 2004). The forebay consists of a separate cell, formed by an acceptable barrier such as a vegetated earthen weir, gabion, or loose riprap wall (California Stormwater Quality Association, 2003). To make sediment removal easier, the bottom and side slopes of the forebay may be lined with concrete (Urban Drainage and Flood Control District, 2005). Direct maintenance access shall be provided to the forebay.
- Inlet design considerations shall include energy dissipaters to reduce inflow velocity, scour potential, and the turbulence and mixing currents that disturb sedimentation (California Stormwater Quality Association, 2003).

- The EWDB outlet structure shall be designed to discharge the WQv over a period of 40 hours (Urban Drainage and Flood Control District, 2005). Refer to Section 6 of this manual for methodology to determine the WQv. When computer software is used to size the water quality outlet, a drawdown of 40 hours is reached when at least 90 percent of the WQv has exited the basin within 40 hours.
- Locate basin outlet as far away from basin inlet(s) as possible to prevent water from short-circuiting the facility. The flow path(s) should have a minimum length of three times the facility width, as measured across the center of the facility in the smallest dimension at the permanent pool elevation (Metropolitan Nashville – Davidson County, 2000).
- Permanent pool depths optimally range from 4 feet to 6 feet, and shall be no greater than 12 feet (California Stormwater Quality Association, 2003). The minimum depth of 4 feet shall be provided in addition to an estimated depth of sediment accumulation from 5 years of EWDB service. Annual sediment accumulation depth can be estimated based on characteristics of the tributary area to the facility. This estimate is illustrated in the design example at the end of this section (Kansas City Metropolitan Chapter of the American Public Works Administration, 2006). This minimum depth requirement prevents vegetation from encroaching on the pond open water surface. The maximum mean depth of 12 feet prevents thermal stratification that can result in potential nutrient release problems associated with anaerobic conditions (Metropolitan Nashville – Davidson County, 2000). If the facility is to contain fish, at least one-quarter of the area of the permanent pool must have a minimum depth of 10 feet plus a sedimentation allowance (Kansas City Metropolitan Chapter of the American Public Works Administration, 2006).
- Side slopes above the littoral bench shall be 4:1 (H:V) or flatter unless retaining walls are used. Side slopes below the littoral bench can be as steep as 3:1 to maximize permanent pool volumes where needed (Metropolitan Nashville – Davidson County, 2000).
- The sides of earthen berms and walls shall be vegetated with native vegetation to prevent erosion (Metropolitan Nashville – Davidson County, 2000).
- Do not locate EWDBs on fill sites or on or near steep slopes if it is expected that much of the water will exit through the bottom of the facility, unless the bottom of the facility is modified to prevent excessive infiltration. Depending on soils, bottom modifications can include compaction, incorporating clay into the soil, or an artificial liner (Metropolitan Nashville – Davidson County, 2000).
- Erosion protection shall be placed at the facility's outfall. Energy dissipation may be required to reduce flow velocities from the primary spillway to nonerosive values (California Stormwater Quality Association, 2003).
- A maintenance ramp and perimeter access shall be included in the design to facilitate access to the basin for maintenance activities (California Stormwater Quality Association, 2003). A 15-foot-wide access strip, with slopes less than 5:1 (H:V) shall be provided around the perimeter of the facility, unless it can be demonstrated that all points of the facility can be maintained with less access provided. The property owner shall also maintain a minimum 15-foot-wide access route to the facility from a street or parking lot (Kansas City Metropolitan Chapter of the American Public Works Administration, 2006).
- The maximum water surface shall be a minimum of 20 feet from property lines and building structures. A greater distance may be necessary when the detention facility might compromise foundations or slope stability is a consideration (Kansas City Metropolitan Chapter of the American Public Works Administration, 2006).
- Ponds that serve smaller local site runoff do not offer as much recreational benefit as ponds serving larger tributary areas. Larger facilities can often be landscaped to offer recreational and aesthetic benefits. Jogging and walking trails, picnic areas, ball fields, and canoeing or boating are some of the typical uses. For example, portions of the facility used for flood control can be kept dry, except during floods, and can be used for exercise areas, soccer fields, or football fields. Wildlife benefits can also be provided in the form of

islands or preservation zones, which allow a view of nature within the park schemes (Metropolitan Nashville – Davidson County, 2000).

- Bedrock must be considered because excavation may be required for grading of a permanent pool. The cost to excavate into bedrock will be significantly higher than the cost to excavate soil. Furthermore, if there is highly fractured bedrock or karst topography, then the siting of an EWDB should be carefully considered because it may not hold water and the additional water flow and/or weight could intensify karst activity (Metropolitan Nashville – Davidson County, 2000).
- EWDBs that do not provide flood storage for the 1 percent storm shall be designed so that runoff flows from the 1 percent event safely pass through the facility. At a minimum, all facility embankments shall be protected from failure during the 1 percent event. An emergency spillway, which conveys large flood flows safely past earth embankments, must be provided for each dam, unless the principal spillway is large enough to pass the peak flow expected from the 1 percent design storm without overtopping the dam (Natural Resources Conservation Service – Maryland, 2000).
- Outflow structures shall be protected by well screen, trash racks, grates, stone filters, submerged inlet pipes to the outflow structure, or other approved devices to ensure that the outlet works will remain functional (Kansas City Metropolitan Chapter of the American Public Works Administration, 2006). No single outlet orifice shall be less than 4 inches in diameter (smaller orifices are more susceptible to clogging). If the calculated orifice diameter necessary to achieve a 40-hour drawdown is less than 4 inches, a perforated riser, orifice plate, or v-notch weir shall be used instead of a single orifice outlet. Keep perforations larger than 1 inch when using orifice plates or perforated risers. Smaller orifice sizes may be used if the weir plate is placed in a riser manhole in a sump-like condition.
- A reverse-slope pipe can be used to prevent outlet clogging from debris. A reverse-slope pipe draws from below the permanent pool extending in a reverse angle up to the riser and establishes the water elevation of the permanent pool. Because these outlets draw water from below the level of the permanent pool, they are less likely to be clogged by floating debris (California Stormwater Quality Association, 2003).
- All pipes through material subject to saturation within earth embankments, regardless of their designated purposes, shall be fitted with watertight cutoff collars or other accepted means of controlling seepage. Such collars shall be of sufficient size and number so as to increase the length of the seepage path along the pipe by at least 15 percent. Spacing between collars shall be 20 to 25 feet. When a single collar is to be used, it shall be placed on the pipe near the point where the centerline of the dam intersects the pipe. If two or more collars are to be installed, they shall generally be placed within the middle third of the pipe length. Generally, such collars should project a minimum of 2 feet beyond the outside of the pipe, regardless of pipe size, and should be no closer than 2 feet to a field joint (Kansas State Board of Agriculture, Division of Water Resources, 1986).
- The facility shall have a separate drain pipe with a manual valve that can completely drain the pond for maintenance purposes. To allow for possible sediment accumulation, the submerged end of the pipe shall be protected, and the drain pipe shall be sized to drain the pond within 24 hours (California Stormwater Quality Association, 2003). The valve shall be located at a point where it can be operated in a safe and convenient manner at all times. Complete gravity drawdown may be impossible for excavated ponds, and a pump may be required to drain the permanent pool.
- Design EWDBs to deter large numbers of geese from gathering in the facility. Geese can add to the nutrient and fecal coliform loads entering and leaving the facility. Planting a buffer of trees, shrubs, and native ground cover around the EWDB can help discourage resident geese populations.
- Public safety shall be considered in EWDB design. Fences and landscaping can be used to impede access to the facility. The facility shall be contoured so as to eliminate any dropoffs or other hazards. The primary spillway opening must not permit access by small children. Outfall pipes above 48 inches in diameter shall

be fenced (California Stormwater Quality Association, 2003). When possible, terraces or benches shall be used to transition into the permanent pool. In some cases there is not sufficient room for grading of this type and the pond may require a perimeter fence (Metropolitan Nashville – Davidson County, 2000).

- Reference Section 44 Additional Practices for Hot Spots for facilities that receive stormwater from contributing areas that have high potential for oil and grease contamination.
- Dams that are greater than 10 feet in height but do not fall into state or federal requirement categories shall be designed in accordance with the latest edition of SCS Technical Release No. 60, Earth Dams and Reservoirs, as Class C structures (Kansas City Metropolitan Chapter of the American Public Works Administration, 2006).
- To maintain a permanent pool, the tributary area to the EWDB should be at least 5.5 acres for each acre-foot of permanent pool volume and at least 10.3 acres for each acre of permanent pool surface area. Table 8.7 presents threshold tributary areas for different Rational C values.

### 8.10.6 Maintenance and Inspections

The success of an EWDB as a mechanism to benefit water quality is dependent on maintaining the permanent pool, vegetation, skimmer devices (where employed), and inlet and outlet structures. Key maintenance operations include sediment, floatable, and debris removal from inlets, outlets, and skimmers (Metropolitan Nashville – Davidson County, 2000).

Since EWDBs are often selected for their aesthetic considerations as well as pollutant removal, they are often sited in areas of high visibility. Consequently, floating litter and debris may be removed more frequently than would be required simply to support proper functioning of the basin and outlet. EWDBs in highly visible settings should be checked weekly and after every large storm event for floating litter and debris. The frequency with which litter and debris must be removed to maintain aesthetics will vary based on the land use of the contributing area to the facility. The inspection schedule can be altered once aesthetic maintenance requirements are established for a particular site. Vegetation management in the area surrounding the EWDB can also contribute substantially to the overall maintenance requirements (California Stormwater Quality Association, 2003).

Typical activities and frequencies include:

- Inspect the facility semiannually for burrows, sediment accumulation, structural integrity of the outlet, and litter accumulation (California Stormwater Quality Association, 2003). The banks of the EWDB should be checked and areas of erosion repaired. Remove sediments if they are within 18 inches of an outlet opening (Metropolitan Nashville – Davidson County, 2000).
- Trim or harvest vegetation as appropriate to maintain water quality, maintenance access, and aesthetics. Once vegetation reaches maximum density in an EWDB, vegetative growth may slow and consequently so will nutrient uptake. Routine vegetation harvesting may increase a facility’s nutrient removal efficiency by providing room for new vegetation to grow. Regular harvesting also prevents outlets from clogging, and the export of nutrients and storage volume reduction from dead and dying plants falling in the water (California Stormwater Quality Association, 2003). Harvested vegetation should be disposed of in a composting facility, yard waste processing center, or landfill. Harvested vegetation shall not be allowed to re-enter the EWDB or downstream water bodies as it would add to the nutrient load.
- Check outlet after each storm event greater than 0.5 inches for clogging and remove any debris.
- Grassy areas shall be mowed annually, unless the unchecked growth of native grass banks interferes with multiuse objectives. Repairs shall be made to signage, walkways, picnic tables, or any other public recreation equipment as needed. If both the operational and aesthetic characteristics of an EWDB are not maintained, then it will be viewed as an eyesore and negative environmental impact even if it is functioning properly (Metropolitan Nashville – Davidson County, 2000).

- Remove sediment when 10 percent to 15 percent of the EWDB permanent pool has been lost. A probing rod can be used to indicate when sediment has reached the depth corresponding to 10 percent to 15 percent of the permanent pool volume (Metropolitan Nashville - Davidson County, 2000).
- Sediment shall be removed when 50 percent of the forebay capacity is silted (Naval Facilities Engineering Service Center, 2004).

#### *8.10.6.1 Sediment Removal*

- Some sediment may contain contaminants of which the Kansas Department of Health and Environment (KDHE) or Missouri Department of Natural Resources (MDNR) requires special disposal procedures. If there is any uncertainty about what the sediment contains or it is known to contain contaminants, then KDHE or MDNR should be consulted and their disposal recommendations followed. Sampling and testing shall be performed on sediments accumulated in facilities serving industrial, manufacturing or heavy commercial sites, fueling centers or automotive maintenance areas, large parking areas, or other areas where pollutants (other than "clean" soil) are suspected to accumulate and be conveyed via stormwater runoff (Metropolitan Nashville – Davidson County, 2000).
- Some sediment collected may be innocuous (free of pollutants other than "clean" soil) and can be used as fill material, cover, or land spreading. It is important that this material not be placed in a way that will promote or allow resuspension in stormwater runoff. The sediment should not be placed within the high water level area of the EWDB, other BMP, creek, waterway, buffer, runoff conveyance device, or other infrastructure. Some demolition or sanitary landfill operators will allow the sediment to be disposed at their facility for use as cover if testing ensures that the sediment is innocuous (Metropolitan Nashville – Davidson County, 2000).

### 8.10.7 Design Example

The following sections present an example for designing an EWDB. These procedures follow the steps outlined in the Design Procedure Form: Extended Wet Detention Basin (EWDB) Main Worksheet. When using the worksheet in electronic form, manually enter values in green.

#### *8.10.7.1 Example*

You are designing an extended wet detention basin to treat stormwater runoff from a 100-acre tributary area that is developed for mixed use, including a shopping center and medium- and high-density residential areas. Size the permanent pool and WQvs of the basin and incorporate an outlet structure that will release the WQv over a period of 40 hours.

**I. Basin Water Quality Volume**

Step 1- Enter the tributary area to the EWDB ($A_T$).

Step 2- Calculate the WQv using the methodology presented in Section 6 of this manual.

**IIa. Permanent Pool Volume, Method 1** (Florida Department of Environmental Regulation, 1988)

This method calculates the permanent pool volume required to provide a minimum detention time of 14 days to allow sufficient time for the uptake of dissolved phosphorus by algae and the settling of fine solids where the particulate phosphorus tends to be concentrated.

Step 1- Enter the average 14-day wet season rainfall ($R_{14}$). Based on the period of record for Kansas City, this is 2.2 inches.

Step 2- Determine the Rational runoff coefficient (C) for the tributary area. This value can be obtained from APWA Section 5602.3 or estimated by delineating pervious and impervious components of the tributary area:

$C = 0.3 + 0.6 * I$; $I$ = percent impervious area divided by 100

Step 3- Calculate the permanent pool volume ($V_{P1}$) from the runoff coefficient, tributary area, and average 14-day wet season rainfall:

$$V_{P1} = (C * A_T * R_{14})/12$$

## IIb. Permanent Pool Volume, Method 2 (EPA, 1986)

This method calculates the permanent pool volume required to settle out suspended solids to the basin bottom.

Step 1- Select the WQv/runoff volume ratio ($V_{B/R}$) from Figure 8.6, based on desired total suspended solids (TSS) removal efficiency. This ratio should be at least 4.

Step 2- Determine the mean storm depth ($S_d$) for your region. For the Kansas City area, this depth is 0.6 inches.

Step 3- Calculate the total impervious tributary area ($A_I$) to the EWDB in acres.

Step 4- Calculate the permanent pool volume ($V_{P2}$) from the values determined in Steps 1, 2, and 3:

$$V_{P2} = (V_{B/R} * S_d * A_i)/12$$

## IIc. Permanent Pool Design Volume

Step 1- Choose the larger of two permanent pool volumes calculated in Parts IIa and IIb and add 20% to account for sedimentation. This value is the design volume (Vp) for the permanent pool.

Step 2- Set desired average permanent pool depth ($Z_P$). This depth should be between 4 feet and 6 feet, unless the pond is being stocked with fish. This average depth should include all parts of the EWDB inundated by the permanent pool, including the littoral bench (Part VI).

Step 3- Calculate the required permanent pool surface area ($A_{PP}$) to accommodate the permanent pool volume calculated in Step 1. This surface area will include the littoral bench (Part VI).

## IIIa. Water Quality Outlet Type

Step 1- Select type of water quality outlet.

Step 2- Proceed to Part IIIb, IIIc, or IIId based on water quality outlet type selected in Step 1.

## IIIb. Water Quality Outlet, Single Orifice (City of Knoxville, 2001)

Step 1- Set depth above WQv outlet ($Z_{WQ}$) based on required WQv and desired facility dimensions (surface area, depth). Facility dimensions should be designed to conform to specific site constraints.

Step 2- Calculate the average head of the WQv over the orifice invert ($H_{WQ}$) as ½ the WQv depth:

$$H_{WQ} = 0.5 * Z_{WQ}$$

Step 3- Calculate the average water quality outflow rate ($Q_{WQ}$) that would result in the entire WQv draining over a period of 40 hours:

$$Q_{WQ} = (WQv * 43{,}560)/(40 * 3{,}600)$$

Step 4- Set the value of the orifice discharge coefficient ($C_O$) based on orifice geometry and thickness of riser/weir plate.

Step 5- Calculate the required water quality outlet orifice diameter ($D_O$) from parameters determined in Steps 2, 3, and 4. Orifice diameter should be larger than 0.5 inches to reduce the chance for clogging.

$$D_o = 12 * 2 * (Q_{WQ}/(C_o * \pi \ * (2 * g * H)^{0.5}))^{0.5}$$

Step 6- To size a single water quality outlet orifice for an EWDB with an irregular stage-volume relationship, use the Single Orifice Worksheet. Fill in the first column with cumulative volume values for each depth interval. The Single Orifice Worksheet uses values from Part IIIb of the Main Worksheet.

IIIc. Water Quality Outlet, Perforated Riser or Plate (Urban Drainage and Flood Control District, 2005)

Step 1 - Set depth above WQv outlet ($Z_{WO}$) based on required WQv and desired facility dimensions (surface area, depth). Facility dimensions should be designed to conform to specific site constraints.

Step 2 - Calculate the recommended maximum outlet area per row of perforations ($A_O$) based on the WQv and the depth at the basin outlet:

$$A_o = WQv/(0.013 * Z_{WQ}^2 + 0.22 * Z_{WQ} - 0.10)$$

Step 3- Assuming a single column, calculate the diameter of a single circular perforation ($D_1$) for each row based on the outlet area calculated in Step 2.

Step 4 - Set the number of columns of perforations ($n_c$). Keep this number as low as possible, optimally 1. If the diameter calculated in Step 3 is greater than 2 inches, make the number of columns greater than 1.

Step 5 - Calculate the design circular perforation diameter ($D_{perf}$) based on the area calculated in Step 2 and the number of columns set in Step 4. Iteratively increase the number of columns until this design diameter is between 1 and 2 inches.

Step 6 - Calculate the horizontal perforation column spacing ($S_c$), center to center, when the number of columns is greater than 1. As long as the perforation diameter calculated in Step 5 is greater than 1, the horizontal perforation column spacing should be 4 inches.

Step 7 - Calculate the number of rows of perforations ($n_r$), center to center, based on a 4-inch vertical spacing and depth at outlet from Step 1.

IIId. Water Quality Outlet, V-Notch Weir (City of Knoxville, 2001)

Step 1 - Set depth above WQv outlet ($Z_{WQ}$) based on required WQv and desired facility dimensions (surface area, depth). Facility dimensions should be designed to conform to specific site constraints.

Step 2 - Calculate the average head of the WQv over the v-notch invert ($H_{WQ}$) as ½ the WQv depth:

$$H_{WQ} = 0.5 * Z_{WQ}$$

Step 3- Calculate the average water quality outflow rate ($Q_{WQ}$) that would result in the entire WQv draining over a period of 40 hours:

$$Q_{WQ} = (WQv * 43{,}560)/(40 * 3{,}600)$$

Step 4- Set the value of the v-notch weir discharge coefficient ($C_v$ =2.5 typical).

Step 5- Calculate the required v-notch weir angle (θ) from parameters determined in Steps 2, 3, and 4. If the calculated v-notch weir angle is less than 20 degrees, set to 20 degrees.

$$\theta = 2 * (180/\pi) * \arctan(Q_{WQ}/(C_v * H_{WQ}^{5/2}))$$

Step 6- Calculate the top width of the v-notch weir ($W_V$):

$$W_v = 2 * Z_{WQ} * TAN(\theta/2)$$

Step 7- To size a v-notch weir for an EWDB with an irregular stage-volume relationship, use the V-Notch Weir Worksheet. Fill in the first column with cumulative volume values for each depth interval. The V-Notch Weir Worksheet uses values from Part IIId of the Main Worksheet.

IV. Trash Racks (Urban Drainage and Flood Control District, 2005)

Step 1- Calculate the total water quality outlet area ($A_{ot}$) from IIIb, IIIc, or IIId, whichever outlet configuration you selected.

Step 2- Calculate the required trash rack open area ($A_t$) from the total outlet area. Figures 8.17 and 8.18 show suggested details for trash racks over perforated riser outlets.

$A_t = A_{ot} * 77 * e^{(-0.124 * D)}$ for single orifice outlet

$A_t = (A_{ot}/2) * 77 * e^{(-0.124 * D)}$ for orifice plate or perforated riser outlet

$A_t = 4 * A_{ot}$ for v-notch weir outlet

V. Forebay (Urban Drainage and Flood Control District, 2005)

Step 1 - Forebay volume ($Vol_{FB}$) should equal at least 10 percent of the WQv calculated in Part I, Step 2.

Step 2 - Set the forebay depth ($Z_{FB}$) as at least 3 feet deep.

Step 3 - Calculate the minimum forebay surface area ($A_{FB}$) from the volume in Step 1 and depth in Step 2.

Step 4 - Ensure that the sides and bottom of the forebay are paved or hardened to ease removal of silt and sedimentation from the forebay.

VI. Littoral Bench (Urban Drainage and Flood Control District, 2005)

Step 1 - Littoral bench should comprise between 25 percent and 50 percent of the total permanent pool surface area calculated in Part IIc, Step 3.

Step 2- Estimate minimum and maximum littoral bench widths based on areas calculated in Step 1. Bench width should be at least 10 feet.

Step 3 - Set desired bench width ($W_{LB}$) within range calculated in Step 2.

Step 4 - Set the bench depth ($Z_{LB}$) between 6 inches and 12 inches below the permanent pool surface.

VII. Basin Side Slopes (Urban Drainage and Flood Control District, 2005)

Basin side slopes should be at least 4:1 (H:V) to facilitate maintenance and public safety. Side slopes should be stabilized, preferably with native vegetative cover.

VIII. Dam Embankment Side Slopes (Urban Drainage and Flood Control District, 2005) (Kansas State Board of Agriculture, Division of Water Resources, 1986)

Dam embankment side slopes should be at least 3:1 (H:V) for public safety. Embankment soils should be compacted to at least 95 percent of their maximum density according to ASTM D 698-70 (Modified Proctor). Embankment slopes should be planted with turf forming grasses. Earth dam designs shall comply with all requirements set forth in the Kansas State Board of Agriculture Division of Water Resources *Engineering Guide – 2*.

IX. Vegetation (Urban Drainage and Flood Control District, 2005)

Basin berms and side slope areas should be planted with native grasses or with irrigated turf to provide erosion control, depending on the local setting and needs. Littoral bench should be planted with native wetland species to promote biological uptake of nutrients. Refer to suggestions and guidelines in Appendix A for vegetation selection and planting design.

X. Inlet Protection (Urban Drainage and Flood Control District, 2005)

Dissipate flow energy at basin’s inflow point(s) to limit erosion and promote particle sedimentation.

XI. Access (Urban Drainage and Flood Control District, 2005)

All-weather stable access to the bottom, forebay, littoral bench, and outlet works area shall be provided for maintenance vehicles. Grades should not exceed 10 percent along access paths, and a solid driving surface of gravel, rock, concrete, or gravel-stabilized turf should be provided.

Table 8.7
Threshold Tributary Areas to EWDB

| | Rational Runoff Coefficient, C | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
| Minimum Tributary Area per Acre-Foot of Volume | 18.4 | 13.8 | 11.0 | 9.2 | 7.9 | 6.9 | 6.1 | 5.5 |
| Minimum Tributary Area per Acre of Surface Area | 34.2 | 25.7 | 20.5 | 17.1 | 14.7 | 12.8 | 11.4 | 10.3 |

## Design Procedure Form: Extended Wet Detention Basin (EWDB)
## Main Worksheet

**Designer:** ____________________
**Checked By:** ____________________
**Company:** ____________________
**Date:** ____________________
**Project:** ____________________
**Location:** ____________________

I. Basin Water Quality Volume

| | | |
|---|---|---|
| Step 1) Tributary area to EWDB, $A_T$ (ac) | $A_T$ (ac) = | 100.0 |
| Step 2) Calculate WQv using methodology in Section 6 | WQv (ac-ft) = | 6.23 |

IIa. Permanent Pool Volume, Method

| | | |
|---|---|---|
| Step 1) Average 14 day wet season rainfall, $R_{14}$ (in) | $R_{14}$ (in) = | 2.2 |
| Step 2) Rational runoff coefficient, C<br>$C = 0.3 + 0.6 * I$<br>I = percent impervious area divided by 100 | C = | 0.6 |
| Step 3) Permanent pool volume by Method 1, $V_{P1}$ (ac-ft)<br>$V_{P1} = (C * A_T * R_{14})/12$ | $V_{P1}$ (ac-ft) = | 11.0 |

IIb. Permanent Pool Volume, Method

| | | |
|---|---|---|
| Step 1) Ratio of basin volume to runoff volume, $V_{B/R}$<br>(from Figure 12; $V_{B/R}$ should be >= 4.0) | $V_{B/R}$ = | 5.0 |
| Step 2) Mean storm depth, $S_d$ (in) | $S_d$ (in) = | 0.60 |
| Step 3) Impervious tributary area, $A_I$ (ac) | $A_I$ (ac) = | 57 |
| Step 4) Permanent pool volume by Method 2, $V_{P2}$ (ac-ft)<br>$V_{P2} = (V_{B/R} * S_d * A_I)/12$ | $V_{P2}$ (ac-ft) = | 14.25 |

IIc. Permanent Pool Design Volume

| | | |
|---|---|---|
| Step 1) Design permanent pool volume, $V_P$, as larger of volumes calculated in IIa and IIb plus 20% | $V_P$ (ac-ft) = | 17.10 |
| Step 2) Average permanent pool depth, $Z_P$ (ft) | $Z_P$ (ft) = | 5.0 |
| Step 3) Permanent pool surface area, $A_P$ (ac) | $A_P$ (ac) = | 3.42 |

IIIa. Water Quality Outlet Type

Step 1) Set water quality outlet type: Outlet Type = 1

Type 1 = single orifice
Type 2 = perforated riser or plate
Type 3 = v-notch weir

Step 2) Proceed to part IIIb, IIIc, or IIId based on water quality outlet type selected

IIIb. Water Quality Pool Outlet, Single Orifice

Step 1) Depth of water quality volume above permanent pool, $Z_{WQ}$ (ft) — $Z_{WQ}$ (ft) = 3.0

Step 2) Average head of water quality volume over invert of orifice, $H_{WQ}$ (ft)

$H_{WQ} = 0.5 * Z_{WQ}$ — $H_{WQ}$ (ft) = 1.5

Step 3) Average water quality outflow rate, $Q_{WQ}$ (cfs)

$Q_{WQ} = (WQv * 43{,}560)/(40 * 3{,}600)$ — $Q_{WQ}$ (cfs) = 1.88

Step 4) Set value of orifice discharge coefficient, $C_o$

$C_o$ = 0.66 when thickness of riser/weir plate is = or < orifice diameter

$C_o$ = 0.80 when thickness of riser/weir plate is > orifice diameter — $C_o$ = 0.66

Step 5) Water quality outlet orifice diameter (minimum of 1/2 inch), $D_o$ (in)

$D_o = 12 * 2 * (Q_{WQ}/(C_o * \pi * (2 * g * H)^{0.5}))^{0.5}$ — $D_o$ (in) = 7.3

(If orifice diameter < 4 inches, use outlet type 2 or 3)

Step 6) To size outlet orifice for EWDB with an irregular stage-volume relationship, use the Single Orifice Worksheet

IIIc. Water Quality Outlet, Perforated Riser

Step 1) Depth of water quality volume above permanent pool, $Z_{WQ}$ (ft) — $Z_{WQ}$ (ft) = 3.0

Step 2) Recommended maximum outlet area per row, $A_o$ (in$^2$)

$Ao = WQv/(0.013 * Z_{WQ}^2 + 0.22 * Z_{WQ} - 0.10)$ — $A_o$ (in$^2$) = 9.2

Step 3) Circular perforation diameter per row assuming a single column, $D_1$ (in) — $D_1$ (in) = 3.42

Step 4) Number of columns, $n_c$ — $n_c$ = 3

Step 5) Design circular perforation diameter (between 1 and 2 inches), $D_{perf}$ (in) — $D_{perf}$ (in) = 1.98

Step 6) Horizontal perforation column spacing when $n_c$ > 1, center to center, $S_c$ — $S_c$ (in) = 4

If $D_{perf}$ >/= 1.0 in, $S_c$ = 4

Step 7) Number of rows (4" vertical spacing between perforations, center to center), $n_r$ — $n_r$ = 9

IIId. Water Quality Outlet, V-Notch Weir[6]

Step 1) Depth of water quality volume above permanent pool, $Z_{WQ}$ (ft) — $Z_{WQ}$ (ft) = 3.0

Step 2) Average head of water quality pool volume over invert of v-notch, HWQ (ft)

$H_{WQ} = 0.5 * Z_{WQ}$ — $H_{WQ}$ (ft) = 1.5

Step 3) Average water quality pool outflow rate, $Q_{WQ}$ (cfs)

$Q_{WQ} = (WQv * 43{,}560)/(40 * 3{,}600)$ — $Q_{WQ}$ (cfs) = 1.88

Step 4) V-notch weir coefficient, $C_v$ — $C_v$ = 2.5

Step 5) V-notch weir angle, $\theta$ (deg)

$\theta = 2 * (180/\pi) * \arctan(Q_{WQ}/(C_v * H_{WQ}^{5/2}))$

V-notch angle should be at least 20 degrees. Set to 20 degrees if calculated angle is smaller. — $\theta$ (deg) = 31

Step 6) V-notch weir top width, $W_v$ (ft) — $W_v$ (ft) = 1.6

$W_v = 2 * Z_{WQ} * TAN(\theta/2)$

Step 7) To calculate v-notch angle for EWDB with an irregular stage-volume relationship, use the V-notch Weir Worksheet

IV. Trash Racks

Step 1) Total outlet area, $A_{ot}$ (in$^2$) — $A_{ot}$ (in$^2$) = 42

Step 2) Required trash rack open area, $A_t$ (in$^2$)

$A_t = A_{ot} * 77 * e^{(-0.124 * D)}$ for single orifice outlet

$A_t = (A_{ot}/2) * 77 * e^{(-0.124 * D)}$ for orifice plate or perforated riser outlet

$A_t = 4 * A_{ot}$ for v-notch weir outlet — $A_t$ (in$^2$) = 1,303

V. Forebay

Step 1) Volume should equal at least 10% of WQv — Min $Vol_{FB}$ (ac-ft) = 0.62

Step 2) Forebay depth, $Z_{FB}$ (ft) — $Z_{FB}$ (ft) = 3.0

Step 3) Minimum forebay surface area, $A_{FB}$ (ac) — Min $A_{FB}$ (ac) = 0.21

Step 4) Paved/hard bottom and sides? — Yes

VI. Littoral Bench

| | | |
|---|---|---|
| Step 1) Littoral bench should be 25% - 50% of the permanent pool surface area | Min $A_{LB}$ (ac) = | 0.86 |
| | Max $A_{LB}$ (ac) = | 1.71 |
| Step 2) Approximate minimum and maximum bench widths, assuming circular permanent pool | Min $W_{LB}$ (ft) = | 27 |
| | Max $W_{LB}$ (ft) = | 54 |
| Step 3) Design bench width around perimeter of EWDB, $W_{LB}$ (ft) | $W_{LB}$ (ft) = | 30 |
| Step 4) Bench depth below permanent pool surface, $Z_{LB}$ (ft) | $Z_{LB}$ (ft) = | 0.5 - 1.0 |

VII. Basin side slopes

| | | |
|---|---|---|
| Basin side slopes should be at least 4:1 (H:V) | Side Slope (H:V) = | 4.0 |

VIII. Dam Embankment side slopes

| | | |
|---|---|---|
| Dam Embankment side slopes should be at least 3:1 (H:V) | Dam Embankment (H:V) = | 3.0 |

IX. Vegetation

Check the method of vegetation planted in the EWDB or describe "other"

_X_ Native Grass
___ Irrigated Turf Grass
_X_ Native Aquatic Species
___ Other: ___ __________
____________________

X. Inlet Protection

| | |
|---|---|
| Indicate method of inlet protection/energy dissipation at EWDB inlet | Rip-rap apron |

## Design Procedure Form: Extended Wet Detention Basin (EWDB)
## Main Worksheet

**Designer:** ____________________
**Checked By:** ____________________
**Company:** ____________________
**Date:** ____________________
**Project:** ____________________
**Location:** ____________________

I. Basin Water Quality Volume

Step 1) Tributary area to EWDB, $A_T$ (ac) — $A_T$ (ac) = ________

Step 2) Calculate WQv using methodology in Section 6 — WQv (ac-ft) = ________

IIa. Permanent Pool Volume, Method

Step 1) Average 14 day wet season rainfall, $R_{14}$ (in) — $R_{14}$ (in) = ________

Step 2) Rational runoff coefficient, C — C = ________

$C = 0.3 + 0.6 * I$

I = percent impervious area divided by 100

Step 3) Permanent pool volume by Method 1, $V_{P1}$ (ac-ft)

$V_{P1} = (C * A_T * R_{14})/12$ — $V_{P1}$ (ac-ft) = ________

IIb. Permanent Pool Volume, Method

Step 1) Ratio of basin volume to runoff volume, $V_{B/R}$

(from Figure 12; $V_{B/R}$ should be >= 4.0) — $V_{B/R}$ = ________

Step 2) Mean storm depth, $S_d$ (in) — $S_d$ (in) = ________

Step 3) Impervious tributary area, $A_I$ (ac) — $A_I$ (ac) = ________

Step 4) Permanent pool volume by Method 2, $V_{P2}$ (ac-ft)

$V_{P2} = (V_{B/R} * S_d * A_I)/12$ — $V_{P2}$ (ac-ft) = ________

IIc. Permanent Pool Design Volume

Step 1) Design permanent pool volume, $V_P$, as larger of volumes calculated in IIa and Iib plus 20% — $V_P$ (ac-ft) = ________

Step 2) Average permanent pool depth, $Z_P$ (ft) — $Z_P$ (ft) = ________

Step 3) Permanent pool surface area, $A_P$ (ac) — $A_P$ (ac) = ________

IIIa. Water Quality Outlet Type

Step 1) Set water quality outlet type: Outlet Type = ________

Type 1 = single orifice

Type 2 = perforated riser or plate

Type 3 = v-notch weir

Step 2) Proceed to part IIIb, IIIc, or IIId based on water quality outlet type selected

IIIb. Water Quality Pool Outlet, Single Orifice

Step 1) Depth of water quality volume above permanent pool, $Z_{WQ}$ (ft) $Z_{WQ}$ (ft) = ________

Step 2) Average head of water quality volume over invert of orifice, $H_{WQ}$ (ft)

$H_{WQ} = 0.5 * Z_{WQ}$ $H_{WQ}$ (ft) = ________

Step 3) Average water quality outflow rate, $Q_{WQ}$ (cfs)

$Q_{WQ} = (WQv * 43{,}560)/(40 * 3{,}600)$ $Q_{WQ}$ (cfs) = ________

Step 4) Set value of orifice discharge coefficient, $C_o$

$C_o$ = 0.66 when thickness of riser/weir plate is = or < orifice diameter

$C_o$ = 0.80 when thickness of riser/weir plate is > orifice diameter $C_o$ = ________

Step 5) Water quality outlet orifice diameter (minimum of 1/2 inch), $D_o$ (in)

$D_o = 12 * 2 * (Q_{WQ}/(C_o * \pi * (2 * g * H)^{0.5}))^{0.5}$ $D_o$ (in) = ________

(If orifice diameter < 4 inches, use outlet type 2 or 3)

Step 6) To size outlet orifice for EWDB with an irregular stage-volume relationship, use the Single Orifice Worksheet

IIIc. Water Quality Outlet, Perforated Riser

Step 1) Depth of water quality volume above permanent pool, $Z_{WQ}$ (ft) $Z_{WQ}$ (ft) = ________

Step 2) Recommended maximum outlet area per row, $A_o$ (in$^2$)

$Ao = WQv/(0.013 * Z_{WQ}^2 + 0.22 * Z_{WQ} - 0.10)$ $A_o$ (in$^2$) = ________

Step 3) Circular perforation diameter per row assuming a single column, $D_1$ (in) $D_1$ (in) = ________

Step 4) Number of columns, $n_c$ $n_c$ = ________

Step 5) Design circular perforation diameter (between 1 and 2 inches), $D_{perf}$ (in) $D_{perf}$ (in) = ________

Step 6) Horizontal perforation column spacing when $n_c > 1$, center to center, $S_c$ $S_c$ (in) = ________

If $D_{perf}$ >/= 1.0 in, $S_c = 4$

Step 7) Number of rows (4" vertical spacing between perforations, center to center), $n_r$ $n_r$ = ________

IIId. Water Quality Outlet, V-Notch Weir[6]

Step 1) Depth of water quality volume above permanent pool, $Z_{WQ}$ (ft) — $Z_{WQ}$ (ft) = ________

Step 2) Average head of water quality pool volume over invert of v-notch, HWQ (ft)

$H_{WQ} = 0.5 * Z_{WQ}$ — $H_{WQ}$ (ft) = ________

Step 3) Average water quality pool outflow rate, $Q_{WQ}$ (cfs)

$Q_{WQ} = (WQv * 43{,}560)/(40 * 3{,}600)$ — $Q_{WQ}$ (cfs) = ________

Step 4) V-notch weir coefficient, $C_v$ — $C_v$ = ________

Step 5) V-notch weir angle, $\theta$ (deg)

$\theta = 2 * (180/\pi) * \arctan(Q_{WQ}/(C_v * H_{WQ}^{5/2}))$

V-notch angle should be at least 20 degrees. Set to 20 degrees if calculated angle is smaller. — $\theta$ (deg) = ________

Step 6) V-notch weir top width, $W_v$ (ft) — $W_v$ (ft) = ________

$W_v = 2 * Z_{WQ} * \mathrm{TAN}(\theta/2)$

Step 7) To calculate v-notch angle for EWDB with an irregular stage-volume relationship, use the V-notch Weir Worksheet

IV. Trash Racks

Step 1) Total outlet area, $A_{ot}$ (in$^2$) — $A_{ot}$ (in$^2$) = ________

Step 2) Required trash rack open area, $A_t$ (in$^2$)

$A_t = A_{ot} * 77 * e^{(-0.124 * D)}$ for single orifice outlet

$A_t = (A_{ot}/2) * 77 * e^{(-0.124 * D)}$ for orifice plate or perforated riser outlet

$A_t = 4 * A_{ot}$ for v-notch weir outlet — $A_t$ (in$^2$) = ________

V. Forebay

Step 1) Volume should equal at least 10% of WQv — Min $Vol_{FB}$ (ac-ft) = ________

Step 2) Forebay depth, $Z_{FB}$ (ft) — $Z_{FB}$ (ft) = ________

Step 3) Minimum forebay surface area, $A_{FB}$ (ac) — Min $A_{FB}$ (ac) = ________

Step 4) Paved/hard bottom and sides? ________

VI. Littoral Bench

Step 1) Littoral bench should be 25% - 50% of the permanent pool surface area — Min $A_{LB}$ (ac) = ________

Max $A_{LB}$ (ac) = ________

Step 2) Approximate minimum and maximum bench widths, assuming circular permanent pool — Min $W_{LB}$ (ft) = ________

Max $W_{LB}$ (ft) = ________

Step 3) Design bench width around perimeter of EWDB, $W_{LB}$ (ft) — $W_{LB}$ (ft) = ________

Step 4) Bench depth below permanent pool surface, $Z_{LB}$ (ft) — $Z_{LB}$ (ft) = ________

VII. Basin side slopes

Basin side slopes should be at least 4:1 (H:V) — Side Slope (H:V) = ________

VIII. Dam Embankment side slopes

Dam Embankment side slopes should be at least 3:1 (H:V) — Dam Embankment (H:V) = ________

IX. Vegetation

Check the method of vegetation planted in the EWDB or describe "other"

___ Native Grass
___ Irrigated Turf Grass
___ Native Aquatic Species
___ Other: ___ __________
____________________

X. Inlet Protection

Indicate method of inlet protection/energy dissipation at EWDB inlet ________

## Variable Dictionary

| Variable | Units | Definition |
|---|---|---|
| $A_I$ | ac | Impervious tributary area |
| $A_{FB}$ | ac | Forebay surface area |
| $A_{LB}$ | ac | Littoral bench area |
| $A_o$ | $in^2$ | Recommended maximum outlet area per row of perforations, for perforated riser or weir plate |
| $A_{ot}$ | $in^2$ | Total open area of outlet structure |
| $A_P$ | ac | Pervious tributary area |
| $A_{PP}$ | ac | Permanent pool surface area |
| $A_t$ | $in^2$ | Total required trash rack open area |
| $A_T$ | ac | Tributary area to EWDB |
| C | none | Rational runoff coefficient |
| $C_o$ | none | Orifice discharge coefficient |
| $C_v$ | none | V-Notch weir discharge coefficient |
| $D_o$ | in | Water quality outlet orifice diameter |
| $D_1$ | in | Circular perforation diameter per row, assuming a single column, for perforated riser or weir plate |
| $D_{perf}$ | in | Design circular perforation diameter for perforated riser or weir plate |
| $H_{WQ}$ | ft | Average head of WQv over invert of water quality outlet |
| I | none | Percent impervious area of tributary area to EWDB divided by 100 |
| $n_c$ | none | Number of columns of perforations for perforated riser or weir plate |
| $n_r$ | none | Number of rows of perforations for perforated riser or weir plate |
| $\theta$ | deg | V-Notch weir angle |
| $Q_{WQ}$ | cfs | Average WQv outflow rate |
| $R_{14}$ | in | Average 14-day wet season rainfall |
| $S_c$ | in | Horizontal perforation column spacing for perforated riser or weir plate |
| $S_d$ | in | Mean storm depth |
| $V_{B/R}$ | none | Ratio of basin volume to runoff volume |
| $V_P$ | ac-ft | Design permanent pool volume, accounts for 20% of basin filling with sediment |
| $V_{P1}$ | ac-ft | Permanent pool volume as calculated by method 1 |
| $V_{P2}$ | ac-ft | Permanent pool volume as calculated by method 2 |
| $Vol_{FB}$ | ac-ft | Pre-sedimentation forebay volume |
| $W_{LB}$ | ft | Littoral bench width |
| $W_v$ | ft | V-notch weir top width |
| WQv | ac-ft | Water quality volume |
| $Z_{FB}$ | ft | Forebay depth |
| $Z_{LB}$ | ft | Littoral bench depth below permanent pool surface |
| $Z_P$ | ft | Average permanent pool depth |
| $Z_{WQ}$ | ft | Depth of WQv above invert of outlet |

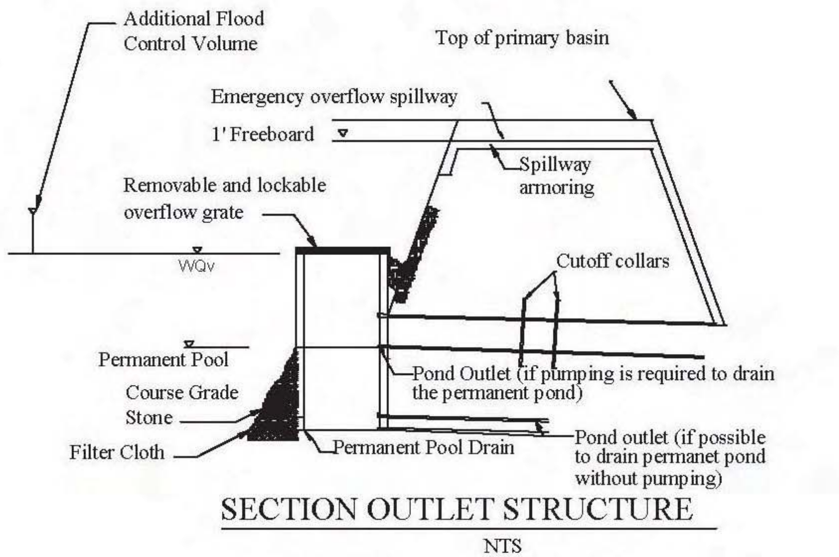
**Part IIIb, Step 5) Water quality outlet orifice diameter derivation from Orifice Equation**

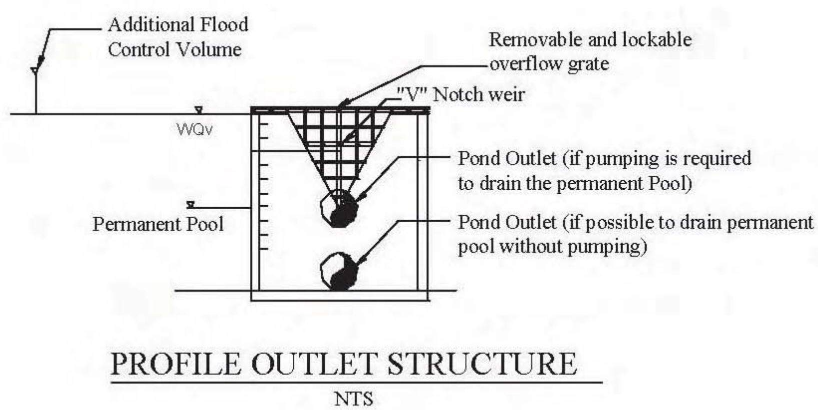
$Q_{WQ} = C_o * A * (2 * g * H)^{0.5}$ (Orifice Equation)

$Q_{WQ} = C_o * (\pi * D_o^2/4) * (2 * g * H)^{0.5}$ ($D_o$ = orifice diameter in feet)

$D_o = \{4 * Q_{WQ}/[C_o * \pi * (2 * g * H)^{0.5}]\}^{0.5}$ (Solve for $D_o$, in feet)

$D_o = 12 * 2 * \{Q_{WQ}/[C_o * \pi * (2 * g * H)^{0.5}]\}^{0.5}$ (Simplify and convert $D_o$ to inches)



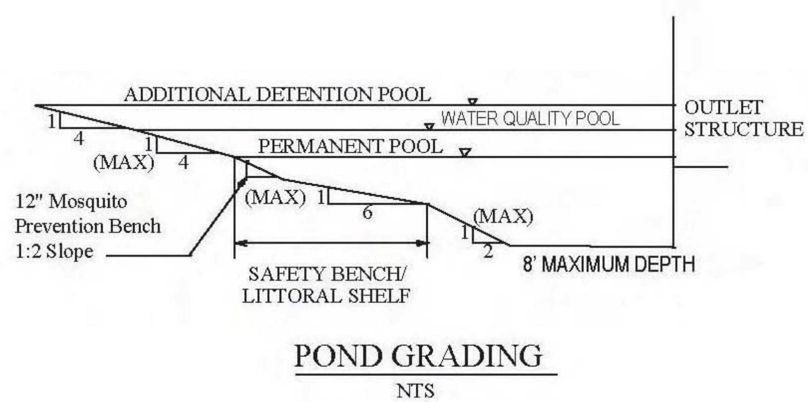
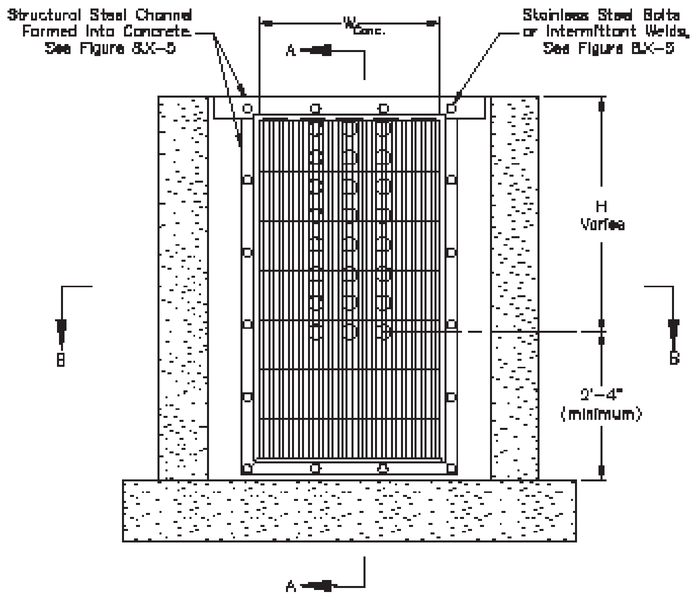




Figure 8.17 - “V” Notch Weir Outlet Structure (2)




Elevation

WQv Trash Racks:

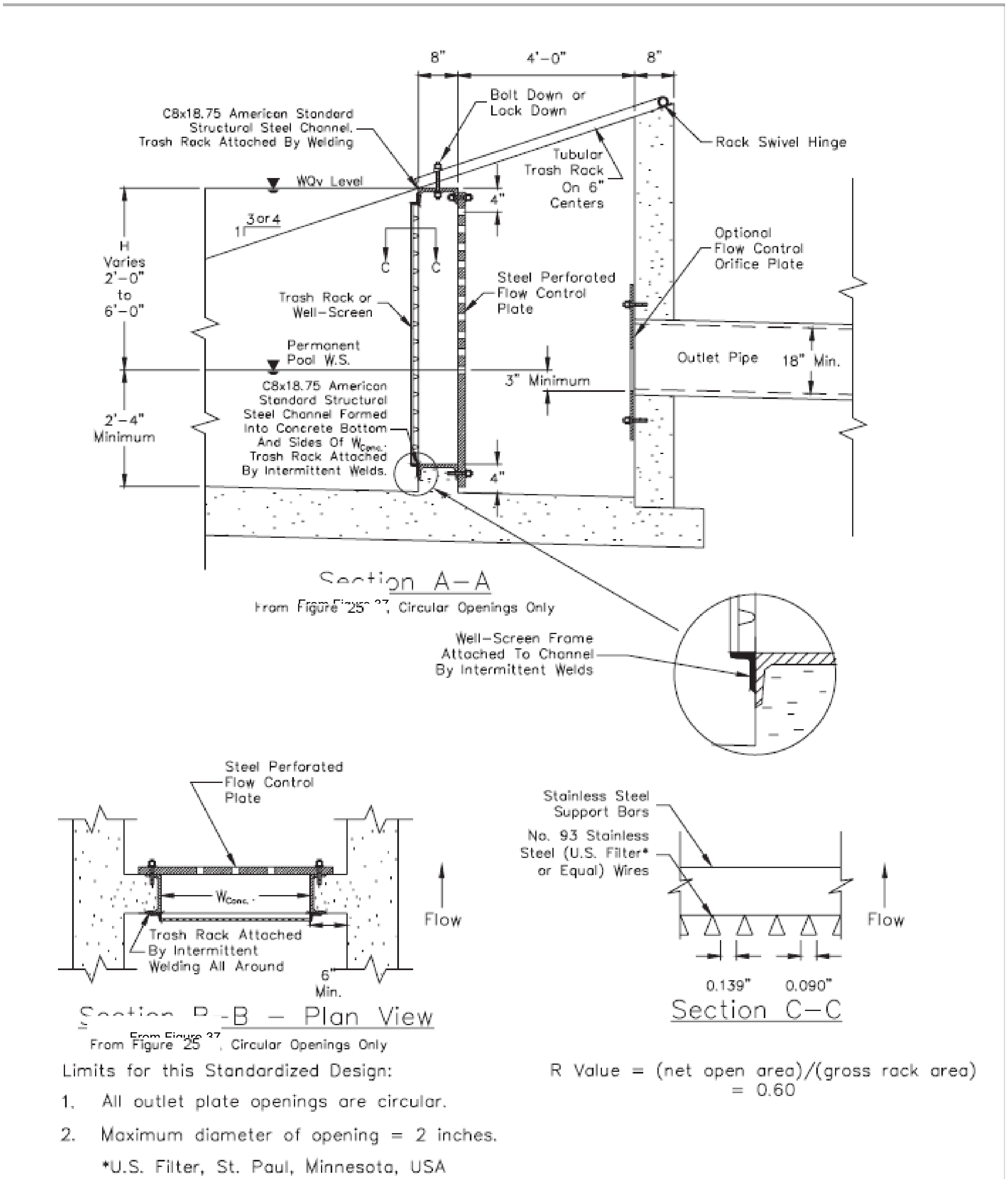
1. Well-screen trash racks shall be stainless steel and shall be attached by intermittant welds along the edge of the mounting frame.
2. Bar grate trash racks shall be aluminum and shall be bolted using stainless steel hardware.
3. Trash Rack widths are for specified trash rack material. Finer well-screen or mesh size than specified is acceptable, however, trash rack dimensions need to be adjusted for materials having a different open area/gross area ratio (R value)
4. Structural design of trash rack shall be based on full hydrostatic head with zero head downstream of the rack.

Overflow Trash Racks:

1. All trash racks shall be mounted using stainless steel hardware and provided with hinged and lockable or boltable access panels.
2. Trash racks shall be stainless steel, aluminum, or steel. Steel trash racks shall be hot dip galvanized and may be hot powder painted after galvanizing.
3. Trash Racks shall be designed such that the diagonal dimension of each opening is smaller than the diameter of the outlet pipe.
4. Structural design of trash rack shall be based on full hydrostatic head with zero head downstream of the rack.

Adapted from Denver Urban Drainage and Flood Control District

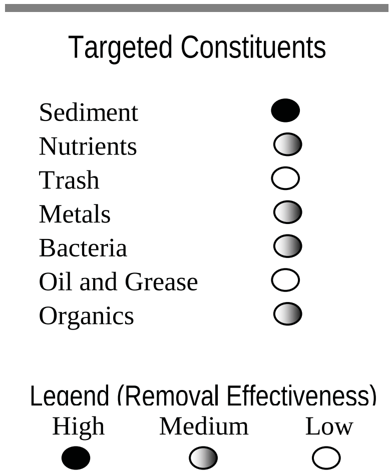
Figure 8.18 - WQv Outlet Trash Rack Design (2)




Adapted from Denver Urban Drainage and Flood Control District

Figure 8.19 - WQv Outlet Trash Rack Design (2)

## 8.11 NATIVE VEGETATION SWALE

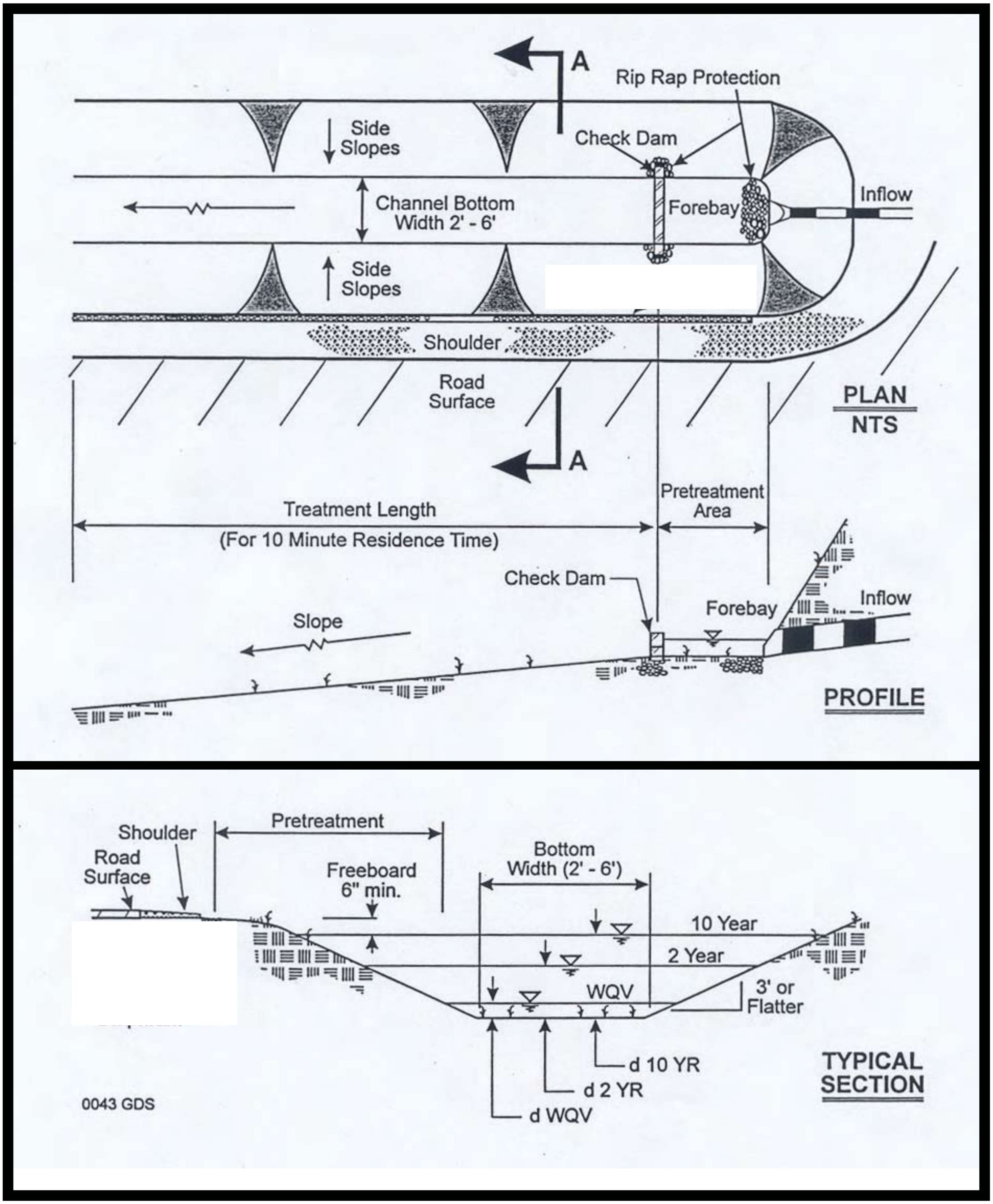



### 8.11.1 Description

Native grass swales are broad, shallow, natural, or constructed channels with a dense native grass stand covering the side slopes and channel bottom. They slowly convey stormwater runoff and, in the process promote infiltration, reduce flow velocities, and pretreat stormwater. Native grass swales can have either parabolic or trapezoidal cross sections and are intended to be used as a substitute for traditional pipe systems to convey roadway, parking lot and other site drainage.

### 8.11.2 General Application

Native grass swales can serve as part of a stormwater drainage system and can replace curb and gutter storm sewer systems. Figure 8.20 illustrates a typical Native Grass Swale. Native grass swales promote infiltration and also help settle many particulate contaminants by slowing flow velocities. Native Grass Swales are intended to treat areas of approximately 5 acres or less to maintain their effectiveness. Larger drainage areas produce too much water for the swale to be effective. Do not use swales as a BMP component to convey deep concentrated flow; swales are only effective conveying shallow concentrated flow. Take care to identify the proper location for a native grass swale. Minimizing disturbance to the area (for example, avoiding application of pesticides and herbicides) maintains the channel’s ability to remove contaminants. Select grass species tolerant of frequent inundation from Appendix A.




Source: CWP 1996

FIGURE 8.20 – Native Vegatation Swale Plan and Profile Example
(for informational purposes only)

## 8.11.3 Advantages

- Constructed less expensively and maintained more easily than underground pipes
- Improve water quality by infiltration, sedimentation and biological uptake
- Reduce total volume of runoff to surrounding streams and rivers
- Minimize erosion by slowing the conveyance of water.

## 8.11.4 Disadvantages

- May require irrigation to establish proper vegetative cover for controlling erosion and reducing pollution in the channel
- May require the use of erosion control or turf reinforcement mats on slopes as prior to full establishment of the vegetation.
- May not be feasible to implement after development has occurred
- Area requirements can be excessive for highly developed sites.
- Require relatively large areas, proper sloping, and connection with other conveyance components
- Not designed to be the fastest conveyance method and, therefore, require exact placement and design to minimize risk of flooding.

## 8.11.5 Design Considerations

The design approach for sizing native grass swales is based on conveying the water quality flow at a shallow depth (<4”). This methodology incorporates a flowrate-based sizing criteria for the water quality, 1%, and 10% frequency storm (see Figure 8.20). Provide bypass for high flows if the swale cannot be stable during the 10% or greater storm.

The following design specifications are summarized in Table 8.8.

### *8.11.5.1 Shape and Slope*

- The swales should generally be trapezoidal in shape, although a parabolic shape is also acceptable (provided the width is equal to or greater than the design bottom width for a trapezoidal cross section). The criteria presented in this section assume a trapezoidal cross section.
- For the trapezoidal cross section, size of the bottom width between two and eight feet. The two feet minimum allows for construction considerations and ensures a minimum filtering surface for water quality treatment. The eight feet maximum reduces the likelihood of flow channelization within a portion of the swale.
- The side slopes of the channel should be no steeper than 3:1 for maintenance and safety considerations. Flatter slopes are encouraged where adequate space is available to aid in providing pretreatment for lateral flows.
- The longitudinal slope of the swale should be moderately flat to provide the slowest flow rate possible. When natural topography necessitates, steeper slopes may be acceptable if check dams (vertical drops of 6 to 12 inches) are used (see Figure 8.21). These structures will require additional energy dissipating measures and should be placed no closer than 50 to 100 foot interval.
- The minimum length of a native grass swale should be 100 feet to provide adequate water quality treatment.

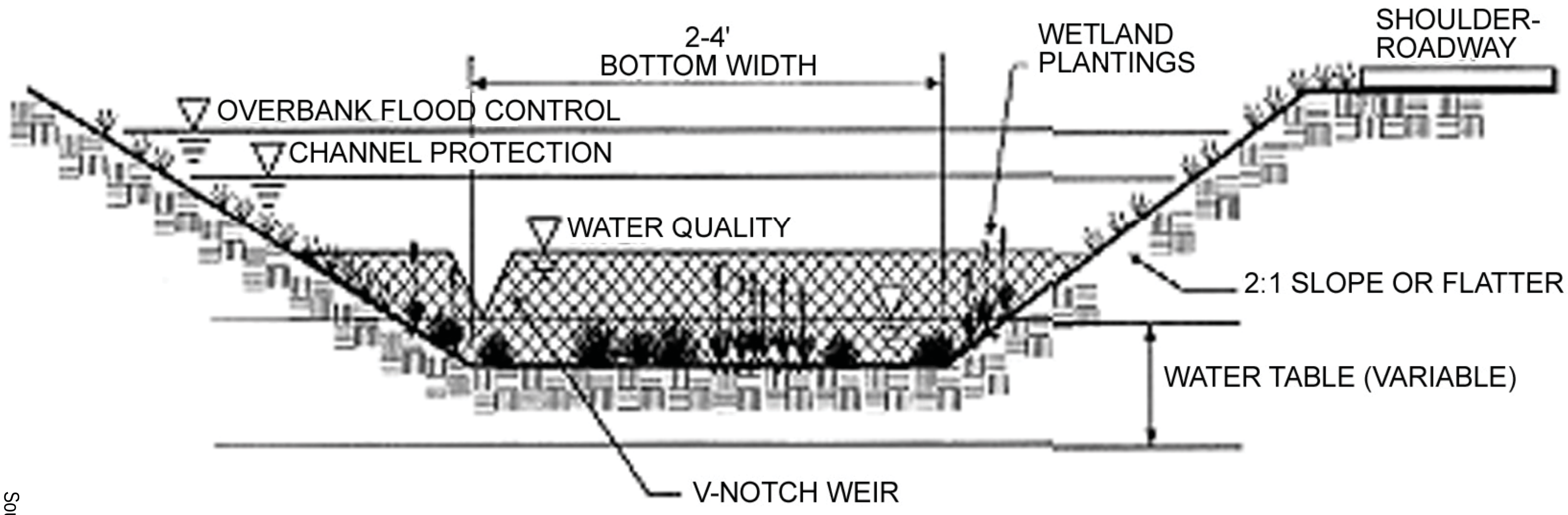
TABLE 8.8
Design Summary for Native Vegetation Swales

| Parameter | Swale Design Criteria |
|---|---|
| Energy Dissipation | Required if piped inflow |
| Preferred Shape | Trapezoidal or Parabolic |
| Bottom Width | 2 feet minimum; 8 feet maximum. |
| Side Slopes | 3:1 or flatter preferred |
| Longitudinal Slope | 1.0% to 2.5% without check dams |
| Underlying soil bed | Undisturbed soils equal to the Swale width No underdrain system |
| Drainage Area | 5 acres or less |
| Minimum Length | Length based on 5-minute residence time, or 100 feet; which ever is greater. |
| Depth and Capacity | Convey the WQf with a maximum depth of 4 inches and a maximum velocity of 1fps<br>Safely convey the 50% event with non-erosive velocity (< 4 fps).<br>Consult local design criteria for flows greater than the 50% storm event. |

*8.11.5.2 Design Size and Soils*

- Design swales to provide a shallow flow depth for the water quality storm (a maximum of 4 inches for the water quality flow is recommended), safely convey the 50% storm with design velocities appropriate for the soil and cover types, and provide adequate capacity for the 10% and 1% storm with a minimum of 1 foot of freeboard if applicable.
- Provide minimum freeboard above 1% storm water surface profile (1.0 foot minimum or as required by local ordinance
- Ensure the soil bed below the swale consists of undisturbed or lightly compacted soils. This area may be periodically inundated and remain wet for long periods of time.
- Do not construct native grass swales in gravelly and coarse sandy soils that cannot easily support dense vegetation.
- In areas with steep slopes, employ native grass swales in locations where they can be parallel to the contours.
- Size swales to convey the 10% and 1% storm volumes and design channel slopes to prevent erosion during the 50% storm events.
- Use outlet protection at any discharge point from native grass swales to prevent scour at the outlet.

- Identify the swale bottom, width, depth, length, and slope necessary to convey the water quality flow rate with a shallow ponding depth (approximate maximum of 4 inches).
- Compute the 50%, 10%, and 1% frequency storm event peak discharges.
- Check the 10% and 1% velocity for erosive potential (adjust swale geometry, if necessary reevaluate WQv design parameters).
- Provide pretreatment to protect the filtering and infiltration capacity of the swale bed. Pretreatment can occur in a sediment forebay behind a check dam with a pipe inlet.
- Use check dams in native grass swales to achieve flatter sections with slower velocities. V-notched weirs in the check dams can be utilized to direct flow and volumes.
- Design native grass swales with trapezoidal or parabolic cross sections, and with side slopes no greater than 3:1 (horizontal:vertical) and bottom widths ranging from 2 to 8 feet.
- Check permissible velocities of selected vegetation to ensure the 50% frequency storm is non-erosive.




Source: Center for Watershed Protection . 2001

FIGURE 8.21 – Typical Native Vegetation Swale Ditch Check
(for informational purposes only)

#### 8.11.5.3 *Vegetative Cover*

- Native grass species selection will depend upon the duration of water inundation, soil type, the amount of sunlight and aesthetic considerations.
- Specify native grass species resistant to periodic inundation and periodic drought.
- Use native plant plugs for initial installation.
- Appropriate soil stabilization methods, such as mulch, blankets or mats should be used before the establishment of vegetation. Seeding, sodding, and other items related to establishing vegetation should be in accordance with accepted erosion-control and planning practices.

### 8.11.6 Maintenance and Inspections

***Source***: Metropolitan Council Environmental Services. 2001 *Minnesota Urban Small Sites BMP Manual,* St. Paul, MN.

The following is a partial list of actions to upkeep wetland swales:

- Inspect swale several times the first few months to ensure plant species are establishing well. If not, reseed or plant an alternative species. Also, inspect the channel for erosion after every rainfall event and repair as necessary.
- If a forebay is used, inspect and remove excessive sediment, trash, and debris and dispose of in an appropriate location.
- Control vegetation by mowing or grubbing techniques (not by chemicals).
- If heavy sediment loading occurs, clean the channel to remove excess particulates.

### 8.11.7 Design Example

#### 8.11.7.1 *Design Calculations*

Step 1 - Find peak flowrate (Q) for tributary area to swale for water quality rainfall event using Rational Method.

$$Q_{WQ} = K \cdot C \cdot i \cdot A$$

Where:

Q = Peak flowrate of runoff (cfs)

C = Runoff Coefficient = 0.3 + 0.6 × I, where I is percent impervious divided by 100

I = Rainfall intensity for water quality rainfall event at the duration equal to the calculated time of concentration (inches/hr) from Section 6.

A =Tributary drainage area (acres)

K =Dimensionless coefficient to account for antecedent precipitation

1.0 for the Water Quality Storm

Step 2 - Solve Manning's equation for a specified variable. For this example, we will calculate flowrate at the maximum allowable depth to verify the swale can carry the proposed peak flowrate. This step is most easily accomplished using a spreadsheet or solver program.

Step 3 - Solve V = Q/A for velocity using calculated variable and Q calculated in Step 1. If V is greater than 1 ft/s, the width of channel, longitudinal slope of channel, or Manning's n value may need to be adjusted to obtain a velocity less than 1 fps, and therefore appropriate for shallow flow.

Step 4 – Solve for the minimum swale length: L = V x 5 min x 60 sec/min . Minimu 100 feet.

Step 5 - Find peak flowrate (Q) for tributary area to swale for the 50% rainfall event using Rational Method.

Step 6 - Solve V = Q/A for velocity using calculated area and Q calculated in Step 4. If V is greater than 4 ft/s, the shape of channel or longitudinal slope of channel may need to be adjusted to obtain a non-erosive velocity less than 4 fps.

Note that an agency may require that a swale also be designed for conveyance of a defined design storm (e.g. 10% or 1% storm event). Additional calculations may be necessary to size the swale for other larger events.

*8.11.7.2 Design Example*

A 1.73-acre commercial site is being developed on a previously undeveloped site and proposes using a native vegetation swale to carry stormwater runoff and treat the water quality event. The swale will be 7-feet wide with 5:1 side slopes and a longitudinal slope of 1.0%. The site's runoff coefficient, C, is 0.67 with an assumed 10 minute time of concentration. Verify the swale design with the BMP manual guidelines.

Step 1 - Calculate the water quality rainfall event Q using the Rational Method. Methodology can be found in Section 6 of this manual.

Q = (1.0)*(0.67)*(1.68 in/hr)*(1.73acre) = 1.95 cfs

Step 2 - Using a solver program, peak flow rate for a 4-inch flow depth in the swale was calculated using Manning's equation.

Trapezoidal (5:1) Swale Example

| n value | Depth (D) feet | Width (W) feet | Area (A) ($ft^2$) | Wetted Perimeter (ft) | Hydraulic Radius ($R_h$) (ft) | Longitudinal Slope (ft/ft) | Iterated Q (CFS) |
|---|---|---|---|---|---|---|---|
| 0.09 | 0.17 | 7.00 | 2.86 | 10.37 | 0.28 | 0.01 | 1.99 |

The proposed swale can carry 1.99 cfs at a 4-inch depth; therefore the swale will carry the Water Quality peak flow of 1.95 cfs below the maximum 4-inch depth.

Step 3 - Calculate Velocity.

V = (1.99 cfs)/(2.86 $ft^2$) = 0.70 ft/s. This is less than 1 ft/s, and therefore meets recommendations for the Water Quality Storm.

Step 4 – Calculate Length

L = 0.70 ft/s x 5 min x 60 sec/min = 210 ft

Step 5 - Calculate the 50% rainfall event Q using the Rational Method. Methodology can be found in APWA 5602.

Q =(1.0)* (0.67)*(4.30 in/hr)*(1.76acre) = 5.10 cfs

Step 6 - Using a solver program, 50% storm event flow depth and area in the swale were calculated using Manning's equation.

Trapezoidal (5:1) Swale Example

| n value | Depth (D) feet | Width (W) feet | Iterated Area (A) $ft^2$ | Wetted Perimeter (ft) | Hydraulic Radius($H_R$) (ft) | Long Slope (ft/ft) | Q (CFS) |
|---|---|---|---|---|---|---|---|
| 0.09 | 0.58 | 7.00 | 5.45 | 12.68 | 0.43 | 0.01 | 5.10 |

V = (5.10 cfs)/(5.45 $ft^2$) = 0.94 ft/s. This is less than 4 ft/s, and therefore meets recommendations for non-erosive velocities.

## 8.12 EXTENDED DRY DETENTION BASIN

Source: California Stormwater Quality Association, 2003.

**Targeted Constituents**

| | |
|---|---|
| Sediment | ◍ |
| Nutrients | ○ |
| Trash | ● |
| Metals | ◍ |
| Bacteria | ◍ |
| Oil and Grease | ○ |
| Organics | ◍ |

Legend (Removal Effectiveness)

| High | Medium | Low |
|---|---|---|
| ● | ◍ | ○ |

### 8.12.1 Description

Extended dry detention basins (EDDBs) are designed to detain the stormwater water quality volume (WQv) for 40 hours to allow particles and associated pollutants to settle (Urban Drainage and Flood Control District, Denver, Colorado, 2005). Unlike extended wet detention basins, these facilities do not maintain a permanent pool between storm events (California Stormwater Quality Association, 2003). However, EDDBs may develop wetland vegetation and sometimes shallow pools in the bottom portions of the facilities (e.g., sediment forebays) that can enhance the basin’s soluble pollutant removal efficiency through maintenance removal and biological uptake (Urban Drainage and Flood Control District, Denver, Colorado, 2005).

### 8.12.2 General Application

EDDBs can be used to improve stormwater runoff quality and reduce peak stormwater runoff rates and peak stages. If these basins are constructed early in the development cycle, they can also be used to trap sediment from construction activities within the tributary drainage area. The accumulated sediment, however, will need to be removed after upstream land disturbances cease and before the basin is placed into final long-term use.

EDDBs can be used to improve the quality of urban runoff coming from roads, parking lots, residential neighborhoods, commercial areas, and industrial sites, and are generally used for site or regional treatment (Urban Drainage and Flood Control District, Denver, Colorado, 2005). They can be used as an onsite BMP that works well with other BMPs, such as upstream onsite source controls and downstream infiltration/filtration basins or wetland channels. If desired, additional volume can be provided in an EDDB for flood control benefits (Urban Drainage and Flood Control District, Denver, Colorado, 2005).

### 8.12.3 Advantages

- Because of the simplicity of design, extended detention basins are relatively easy and inexpensive to construct and operate (California Stormwater Quality Association, 2003).
- EDDBs can provide substantial capture of sediment and the pollutants adsorbed onto the surfaces of the particles (California Stormwater Quality Association, 2003).
- Widespread application of EDDBs with sufficient capture volume can provide significant control of channel erosion and enlargement caused by changes to flow frequency relationships resulting from the increase of impervious cover in a watershed (California Stormwater Quality Association, 2003).

- EDDBs can be designed to provide other benefits, such as recreation and open space opportunities, in addition to reducing peak runoff rates and improving water quality (Urban Drainage and Flood Control District, Denver, Colorado, 2005) (Metropolitan Nashville – Davidson County, 2000).

### 8.12.4 Disadvantages

- EDDBs have only moderate pollutant removal when compared to some other structural stormwater practices, and they are relatively ineffective at removing soluble pollutants (California Stormwater Quality Association, 2003).
- Dry ponds can potentially detract from the value of a home because of the adverse aesthetics of dry, bare areas and inlet and outlet structures; however, wet ponds can increase property values (California Stormwater Quality Association, 2003).

### 8.12.5 Design Requirements and Considerations

The following guidelines shall be considered when designing EDDBs (Figure 8.22):

- EDDBs shall be designed to limit environmental impacts downstream when maintaining the facility (Metropolitan Nashville – Davidson County, 2000). EDDBs shall be placed outside of stream corridors and stream buffer zones.
- Capture volume shall be sized to treat the WQv and discharge over a period of 40 hours. Refer to Section 6 of this manual.
- When computer software is used to size the water quality outlet, a drawdown of 40 hours is reached when at least 90 percent of the WQv has exited the basin within 40 hours.
- A sediment forebay shall be incorporated into the EDDB design to trap sediment and trash at all basin inlets, where the sediment and trash can be more easily removed than from the permanent pool (Kansas City Metropolitan Chapter of the American Public Works Administration, 2006). The forebay shall be at least 10 percent of the WQv and shall be 4 to 6 feet deep. The forebay can also facilitate maintenance by concentrating sediment in an accessible location. The forebay consists of a separate cell, formed by an acceptable barrier such as a vegetated earthen weir. To make sediment removal easier, the bottom and side slopes of the forebay may be lined with concrete (Urban Drainage and Flood Control District, Denver, Colorado, 2005) (Camp Dresser & McKee, Inc., 2005). This area should be designed to minimize aesthetic problems associated with sediment and debris accumulation and saturated soils in this portion of the basin (Camp Dresser & McKee, Inc., 2005). Other pretreatment devices and processes may also be applicable.
- Additional design inlet considerations should include energy dissipaters to reduce inflow velocity, scour potential, and the turbulence and mixing currents that disturb sedimentation (Urban Drainage and Flood Control District, Denver, Colorado, 2005) (Camp Dresser & McKee, Inc., 2005).
- Locate basin outlet as far away from basin inlet as possible to prevent water from short-circuiting the facility (Metropolitan Nashville – Davidson County, 2000).
- Basin depths shall range from 2 feet to 5 feet for the WQv (California Stormwater Quality Association, 2003). A shallow pond with large surface area performs better than a deep pond with the same volume (Metropolitan Nashville – Davidson County, 2000).
- Side slopes shall be at least 4:1 (H:V) if basin is designed for the WQv only (Metropolitan Nashville – Davidson County, 2000). A side slope of 3:1 is acceptable for basins designed to capture flood flows.
- Vegetate side slopes and bottom using native vegetation to the maximum extent practical (Metropolitan Nashville – Davidson County, 2000).
- Provide embankment freeboard of at least 1 foot when detaining the WQv only. If flood storage volume is also included in the design, refer to Section 5600 for embankment design criteria.

- Do not locate EDDBs on fill sites or on or near steep slopes if it is expected that much of the water will exit through the bottom of the facility, unless the bottom of the facility is modified to prevent excessive infiltration (Metropolitan Nashville – Davidson County, 2000).
- Energy dissipation shall be included in the inlet design to reduce resuspension of accumulated sediment (California Stormwater Quality Association, 2003).
- Erosion protection shall be placed at the facility's outfall. Energy dissipation may be required to reduce flow velocities from the primary spillway to nonerosive values (California Stormwater Quality Association, 2003).
- A maintenance ramp and perimeter access shall be included in the design to facilitate access to the basin for maintenance activities (California Stormwater Quality Association, 2003).
- When desirable and feasible, EDDBs shall be incorporated within a larger flood control basin or as a part of a full-spectrum detention facility. See APWA 5600 for design specifications if flood control is to be incorporated into the design of the EDDB. Also, whenever possible, designers should try to accommodate within the basin other urban uses such as passive recreation and wildlife habitat (Urban Drainage and Flood Control District, Denver, Colorado, 2005).
- EDDBs that do not provide flood storage for the 1 percent storm shall be designed so that runoff flows from the 1 percent event safely pass through the facility. At a minimum, all facility embankments shall be protected from failure during the 1 percent event. An emergency spillway, which conveys large flood flows safely past earth embankments, must be provided for each dam unless the principal spillway is large enough to pass the peak flow expected from the 1 percent design storm without overtopping the dam (Natural Resources Conservation Service – Maryland, 2000).
- The EDDB bottom should be 1 to 2 feet above the wet season groundwater table, as groundwater may surface within the basin or contribute baseflow to the basin (Urban Drainage and Flood Control District, Denver, Colorado, 2005). This also allows for some infiltration.
- Outflow structures shall be protected by well screen, trash racks, grates, stone filters, or other approved devices to ensure that the outlet works will remain functional (Kansas City Metropolitan Chapter of the American Public Works Administration, 2006). No single outlet orifice shall be less than 4 inches in diameter (smaller orifices are more susceptible to clogging). If the calculated orifice diameter necessary to achieve a 40-hour drawdown is less than 4 inches, a perforated riser, orifice plate, or v-notch weir shall be used instead of a single orifice outlet. Keep perforations larger than 1 inch when using orifice plates or perforated risers. Smaller orifice sizes may be used if the weir plate is placed in a riser manhole in a sump-like condition.
- Public safety shall be considered in EDDB design. Fences and landscaping can be used to impede access to the facility. The facility shall be contoured so as to eliminate any dropoffs or other hazards. The primary spillway opening must not permit access by small children. Outfall pipes above 48 inches in diameter shall be fenced (California Stormwater Quality Association, 2003).
- Facilities that receive stormwater from contributing areas that have potential for oil and grease contamination must include a baffle, skimmer, and grease trap to prevent these substances from being discharged from the facility (Metropolitan Nashville – Davidson County, 2000).

### 8.12.6 Maintenance and Inspections

Routine maintenance activity is often thought to consist mostly of sediment and trash and debris removal; however, these activities often constitute only a small fraction of the maintenance hours. Often, the largest EDDB maintenance activity in terms of labor hours is vegetation management, such as routine mowing (California Stormwater Quality Association, 2003).

Consequently, maintenance costs should be estimated based primarily on the mowing frequency and the time required. Mowing should be done at least annually to avoid establishment of woody vegetation, but may need to be performed much more frequently if aesthetics are an important consideration (California Stormwater Quality Association, 2003).

Typical activities and frequencies include:

- Schedule semiannual inspection for the beginning and end of the wet season and after each extreme storm event for standing water, slope stability, sediment accumulation, trash and debris, and presence of burrows (California Stormwater Quality Association, 2003) (Metropolitan Nashville – Davidson County, 2000). The banks and bottom of the EDDB shall be checked and areas of erosion repaired. Remove nuisance wetland species and take appropriate measures to control mosquitoes. Remove sediments if they are within 18 inches of an orifice plate (Metropolitan Nashville – Davidson County, 2000).
- Remove accumulated trash and debris in the basin and around the outlet structure during the semiannual inspections. The frequency of this activity may be altered to meet specific site conditions (California Stormwater Quality Association, 2003).
- Trim vegetation at the beginning and end of the wet season and inspect monthly to prevent establishment of woody vegetation and for aesthetic and vector reasons (California Stormwater Quality Association, 2003).
- Check outlet after each storm event greater than 0.5 inches for clogging and remove any debris.
- Grassy areas shall be mowed annually, unless the unchecked growth of native grass banks interferes with multiuse objective. Repairs shall be made to signage, walkways, picnic tables, or any other public recreation equipment as needed. If both the operational and aesthetic characteristics of a dry pond are not maintained, then it will be viewed as an eyesore and negative environmental impact even if it is functioning properly (Metropolitan Nashville – Davidson County, 2000).
- Remove sediment when accumulation reaches 6 inches, or if resuspension is observed or probable. Sediment may be permitted to accumulate deeper than 6 inches if there is a permanent marker indicating the depth where sediment needs to be removed and that mark has not been met (Metropolitan Nashville – Davidson County, 2000).

#### *8.12.6.1 Sediment Removal*

Some sediment may contain contaminants of which the Kansas Department of Health and Environment (KDHE) or Missouri Department of Natural Resources (MDNR) requires special disposal procedures. If there is any uncertainty about what the sediment contains or it is known to contain contaminants, then KDHE or MDNR should be consulted and their disposal recommendations followed. Sampling and testing shall be performed on sediments accumulated in facilities serving industrial, manufacturing or heavy commercial sites, fueling centers or automotive maintenance areas, large parking areas, or other areas where pollutants (other than “clean” soil) are suspected to accumulate and be conveyed via stormwater runoff (Metropolitan Nashville – Davidson County, 2000).

Some sediment collected may be innocuous (free of pollutants other than “clean” soil) and can be used as fill material, cover, or land spreading. It is important that this material not be placed in a way that will promote or allow resuspension in stormwater runoff. The sediment shall not be placed within the high water level area of the EDDB, other BMP, creek, waterway, buffer, runoff conveyance device, or other infrastructure. Some demolition or sanitary landfill operators will allow the sediment to be disposed at their facility for use as cover. This generally requires that the sediment be tested to ensure that it is innocuous (Metropolitan Nashville – Davidson County, 2000).

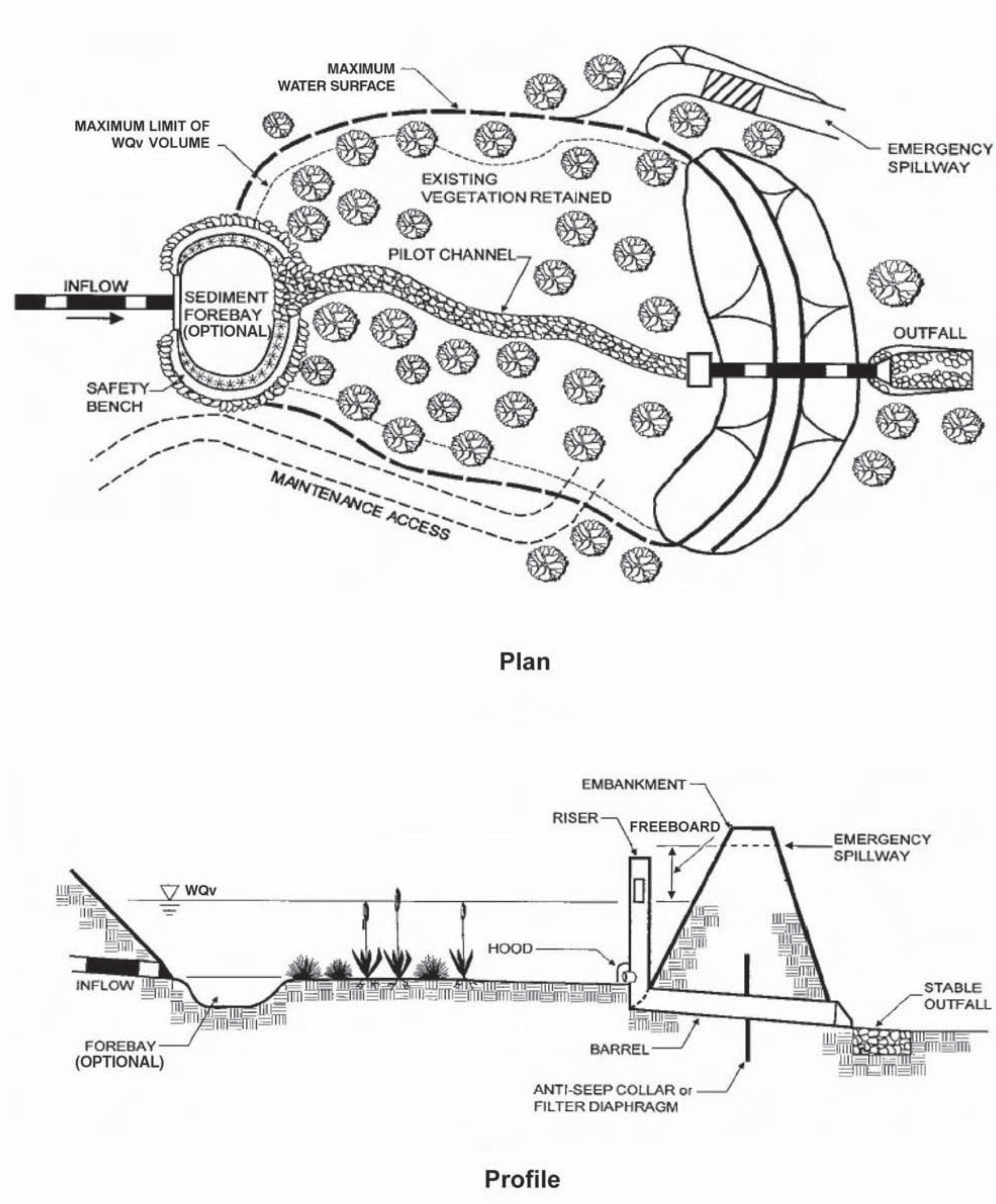



Figure 8.22 - Schematic of an Extended Dry Detention Basin

(Adapted from Maryland Department of Environment, 2000)

### 8.12.7 Design Example

The following sections present an example for designing an EDDB. These procedures follow the steps outlined in the Design Procedure Form: Extended Dry Detention Basin (EDDB) Main Worksheet. When using the worksheet in electronic form, manually enter values in green.

### *8.12.7.1 Example*

You are developing a 26-acre lot of previously undeveloped land for mixed use, to include a small shopping center and medium density residential areas. Design an extended dry detention basin to treat the water quality rainfall event for the Kansas City Metropolitan Area of 1.4 inches. Incorporate an outlet structure that will release the WQv over a period of 40 hours.

#### I. Basin Water Quality Storage Volume

Step 1 - Enter the tributary area to the EDDB (AT).

Step 2 - Calculate the WQv using the methodology presented in Section 6 of this manual.

Step 3 - Add 20 percent to account for silt and sediment deposition in the basin (Vdesign).

#### IIa. Water Quality Outlet Type

Step 1 - Select type of water quality outlet: single orifice, v-notch weir, or perforated riser/plate.

Step 2 - Proceed to Part IIb, IIc, or IId based on water quality outlet type selected in Step 1.

#### IIb. Water Quality Outlet, Single Orifice (City of Knoxville, 2001)

Step 1 - Set depth above WQv outlet (ZWQ) based on required WQv and desired facility dimensions (surface area, depth). Facility dimensions should be designed to conform to specific site constraints.

Step 2 - Calculate the average head of the WQv over the orifice invert (HWQ) as ½ the WQv depth:

$$H_{WQ} = 0.5 * Z_{WQ}$$

Step 3 - Calculate the average water quality outflow rate ($Q_{WQ}$) that would result in the entire WQv draining over a period of 40 hours:

$$Q_{WQ} = (WQv * 43{,}560)/(40 * 3{,}600)$$

Step 4 - Set the value of the orifice discharge coefficient ($C_O$) based on orifice geometry and thickness of riser/weir plate.

Step 5 - Calculate the required water quality outlet orifice diameter ($D_O$) from parameters determined in Steps 2, 3, and 4. Orifice diameter should be larger than 0.5 inches to reduce the chance for clogging.

$$D_o = 12 * 2 * (Q_{WQ}/(C_o * \pi * (2 * g * H)^{0.5}))^{0.5}$$

Step 6 - To size a single water quality outlet orifice for an EDDB with an irregular stage-volume relationship, use the Single Orifice Worksheet. Fill in the first column with cumulative volume values for each depth interval. The Single Orifice Worksheet uses values from Part IIb of the Main Worksheet.

#### IIc. Water Quality Outlet, Perforated Riser, or Plate

(Urban Drainage and Flood Control District, Denver, Colorado, 2005)

Step 1 - Set depth above WQv outlet ($Z_{WQ}$) based on required WQv and desired facility dimensions (surface area, depth). Facility dimensions should be designed to conform to specific site constraints.

Step 2 - Calculate the recommended maximum outlet area per row of perforations based on the WQv and the depth at the basin outlet:

$$A_o = WQv/(0.013 * Z_{WQ}^2 + 0.22 * Z_{WQ} - 0.10)$$

Step 3 - Assuming a single column, calculate the diameter of a single circular perforation for each row ($D_1$) based on the outlet area calculated in Step 2.

Step 4 - Set the number of columns of perforations ($n_c$). Keep this number as low as possible, optimally 1. If the diameter calculated in Step 3 is greater than 2 inches, make the number of columns greater than 1.

Step 5 - Calculate the design circular perforation diameter ($D_{perf}$) based on the area calculated in Step 2 and the number of columns set in Step 4. Iteratively increase the number of columns until this design diameter is between 1 and 2 inches.

Step 6 - Calculate the horizontal perforation column spacing ($S_C$), center to center, when the number of columns is greater than 1. As long as the perforation diameter calculated in Step 5 is greater than 1, the horizontal perforation column spacing should be 4 inches.

Step 7 - Calculate the number of rows of perforations ($n_r$), center to center, based on a 4-inch vertical spacing and depth at outlet from Step 1.

IId. Water Quality Outlet, V-notch Weir (City of Knoxville, 2001)

Step1 - Set depth above WQv outlet ($Z_{WQ}$) based on required WQv and desired facility dimensions (surface area, depth). Facility dimensions should be designed to conform to specific site constraints.

Step 2- Calculate the average head of the WQv ($H_{WQ}$) over the v-notch invert as ½ the WQv depth:

$$H_{WQ} = 0.5 * Z_{WQ}$$

Step 3- Calculate the average water quality outflow rate ($Q_{WQ}$) that would result in the entire WQv draining over a period of 40 hours:

$$Q_{WQ} = (WQv * 43{,}560)/(40 * 3{,}600)$$

Step 4 - Select the value of the v-notch weir discharge coefficient ($C_v$ = 2.5 typical)

Step 5 - Calculate the required v-notch weir angle (θ) from parameters determined in Steps 2, 3, and 4. If the calculated v-notch weir angle is less than 20 degrees, set to 20 degrees.

$$\theta = 2 * (180/\pi) * \arctan(Q_{WQ}/(C_v * H_{WQ}^{5/2}))$$

Step 6 - Calculate the top width of the v-notch weir:

$$W_v = 2 * Z_{WQ} * \mathrm{TAN}(\theta/2)$$

Step 7 - To size a v-notch weir for an EDDB with an irregular stage-volume relationship, use the V-Notch Weir Worksheet. Fill in the first column with cumulative volume values for each depth interval. The V-Notch Weir Worksheet uses values from Part IId of the Main Worksheet.

## III. Flood Control

If facility is to provide flood control storage in addition to the WQv, design basin to specifications given in the Kansas City Metropolitan Chapter of the American Water Works Association Specifications Section 5608.

## IV. Trash Racks (Urban Drainage and Flood Control District, Denver, Colorado, 2005)

Step 1- Calculate the total water quality outlet area (Aot) from IIb, IIc, or IId, whichever outlet configuration you selected.

Step 2- Calculate the required trash rack open area (At) from the total outlet area. Figures 8.25 and 8.26 show suggested details for trash racks over perforated riser outlets.

$A_t = A_{ot} * 77 * e^{(-0.124 * D)}$ for single orifice outlet

$A_t = (A_{ot}/2) * 77 * e^{(-0.124 * D)}$ for orifice plate or perforated riser outlet

$A_t = 4 * A_{ot}$ for v-notch weir outlet

V. **Basin Shape** (Urban Drainage and Flood Control District, Denver, Colorado, 2005) (City of Knoxville, 2001)

Step 1- The flow path through the facility shall be made as long as possible to increase stormwater runoff residence time in the basin (Urban Drainage and Flood Control District, Denver, Colorado, 2005).

Step 2- A pilot channel can be constructed through the main part of the facility to convey low flows from the forebay to the bottom stage. Make it at least 4 inches deep if concrete lined sides and 8 inches if buried riprap sides are used. At a minimum, provide conveyance capacity equal to twice the release capacity at the upstream forebay outlet (Urban Drainage and Flood Control District, Denver, Colorado, 2005).

Step 3- The top stage is the basin bottom adjacent to the pilot channel on either side. It shall be at least 1 foot deep ($D_{ts}$) with its bottom sloped 1 percent to 2 percent toward the pilot channel ($S_{ts}$) (Urban Drainage and Flood Control District, Denver, Colorado, 2005).

Step 4- The bottom stage is the deep portion of the EDDB around the outlet structure. This part of the basin shall be 1.25 to 3.0 feet deeper than the top stage. The bottom stage shall store 10 percent to 25 percent of the WQv below the top stage ($V_{bs}$).

VI. **Forebay** (Optional) (Urban Drainage and Flood Control District, Denver, Colorado, 2005)

Step 1- Forebay volume ($Vol_{FB}$) should equal at least 10 percent of the WQv calculated in Part I, Step 2.

Step 2- Set the desired peak forebay depth ($Z_{FB}$) in the water quality rainfall event. This depth is commonly maintained with a secondary berm in the EDDB.

Step 3- Calculate the required forebay surface area ($A_{FB}$) based on the volume calculated in Step 1 and peak depth calculated in Step 2.

Step 4- Ensure that the sides and bottom of the forebay are paved or hardened to ease removal of silt and sedimentation from the forebay.

VII. **Basin Side Slopes** (Urban Drainage and Flood Control District, Denver, Colorado, 2005)

Basin side slopes shall be at least 4:1 (H:V) if basin is designed for the water quality control volume only. A side slope of 3:1 is acceptable for basins designed to capture flood flows.

VIII. **Dam Embankment Side Slopes** (Urban Drainage and Flood Control District, Denver, Colorado, 2005) (Kansas State Board of Agriculture, Division of Water Resources, 1986)

Dam embankment side slopes should be at least 3:1 (H:V) for public safety. Embankment soils should be compacted to at least 95 percent of their maximum density according to ASTM D 698-70 (Modified Proctor). Embankment slopes should be planted with turf-forming grasses. Earth dam designs shall comply with all federal, state, and local requirements.

IX. **Vegetation** (Urban Drainage and Flood Control District, Denver, Colorado, 2005)

Bottom vegetation provides erosion control and sediment entrapment. Basin bottom, berms, and side slope areas may be planted with native grasses or with irrigated turf, depending on the local setting and needs. Refer to suggestions and guidelines in Appendix A for vegetation selection and planting design.

X. **Inlet Protection** (Urban Drainage and Flood Control District, Denver, Colorado, 2005)

Dissipate flow energy at basin's inflow point(s) to limit erosion and promote particle sedimentation.

XI. **Access** (Urban Drainage and Flood Control District, Denver, Colorado, 2005)

All-weather stable access to the bottom, forebay, and outlet works area shall be provided for maintenance vehicles. Grades should not exceed 10 percent along access paths, and a solid driving surface of gravel, rock, concrete, or gravel-stabilized turf should be provided.

**Design Procedure Form: Extended Dry Detention Basin (EDDB)**
**Main Worksheet**

| | | | |
|---|---|---|---|
| **Designer:** | | **Date:** | |
| **Checked By:** | | **Project:** | EXAMPLE |
| **Company:** | | **Location:** | |
| | | **Page:** | 1 of 3 |

I. Basin Water Quality Storage Volume

| | | |
|---|---|---|
| Step 1) Tributary area to EDDB, $A_T$ (ac) | $A_T$ (ac) = | **26.0** |
| Step 2) Calculate WQv using methodology in Section 6 | WQv (ac-ft) = | **1.62** |
| Step 3) Add 20 percent to account for silt and sediment deposition in the basin | $V_{design}$ (ac-ft) = | **1.94** |

IIa. Water Quality Outlet Type

Step 1) Set water quality outlet type — Outlet Type = **2**

Type 1 = single orifice
Type 2 = perforated riser or plate
Type 3 = v-notch weir

Step 2) Proceed to Step IIb, IIc, or IId based on water quality outlet type slected

IIb. Water Quality Outlet, Single Orifice

Step 1) Depth of water quality volume at outlet, $Z_{WQ}$ (ft) — $Z_{WQ}$ (ft) = **3.0**

Step 2) Average head of water quality volume over invert of orifice, $H_{WQ}$ (ft)
$H_{WQ} = 0.5 * Z_{WQ}$ — $H_{WQ}$ (ft) = **1.5**

Step 3) Average water quality outflow rate, $Q_{WQ}$ (cfs)
$Q_{WQ} = (WQ_v * 43{,}560)/(40 * 3{,}600)$ — $Q_{WQ}$ (cfs) = **0.49**

Step 4) Set value of orifice discharge coefficient, $C_o$
$C_o = 0.66$ when thickness of riser/weir plate is ≤ orifice diameter
$C_o = 0.80$ when thickness of riser/weir plate is > orifice diameter — $C_o$ = **0.66**

Step 5) Water quality otulet orifice diameter (minimum of 4 inches), $D_o$ (in)
$D_o = 12 * 2 * (Q_{WQ}/(C_o * \pi * (2 * g * H)^{0.5}))^{0.5}$ — $D_o$ (in) = **3.7**
(if orifice diameter < 4 inches, us outlet type 2 or 3)

Step 6) To size outlet orifice for EDDB with an irregular stage-volume relationship, use the Single Orifice Worksheet

IIc. Water Quality Outlet, Perforated Riser

Step 1) Depth at outlet above lowest perforation, $Z_{WQ}$ (ft) — $Z_{WQ}$ (ft) = **3.0**

Step 2) Recommended maximum outlet area per row, $A_o$ (in$^2$)
$A_o = (WQv)/(0.013 * Z_{WQ}^2 + 0.22 * Z_{WQ} - 0.10)$ — $A_o$ (in$^2$) = **2.4**

Step 3) Circular perforation diameter per row assuming a single column, $D_1$ (in) — $D_1$ (in) = **1.75**

Step 4) Number of columns, $n_c$ — $n_c$ = **1**

Step 5) Design circular perforation diameter (should be between 1 and 2 inches), $D_{perf}$ (in) — $D_{perf}$ (in) = **1.75**

Step 6) Horizontal perforation column spacing when $n_c > 1$, center to center, $S_c$ — $S_c$ (in) = **N/A**
If $D_{perf} \geq 1.0$ inch, $S_c = 4$

Step 7) Number of rows (4" vertical spacing between perforations, center to center), $n_r$ — $n_r$ = **9**

## Design Procedure Form: Extended Dry Detention Basin (EDDB)
### Main Worksheet

| | | | |
|---|---|---|---|
| **Designer:** | | **Date:** | |
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IId. Water Quality Outlet, V-notch Weir

Step 1) Depth of water quality volume above permanent pool, $Z_{WQ}$ (ft) — $Z_{WQ}$ (ft) = **3.0**

Step 2) Average head of water quality pool volume over invert of v-notch, $H_{WQ}$ (ft)
$H_{WQ} = 0.5*Z_{WQ}$ — $H_{WQ}$ (ft) = **1.5**

Step 3) Average water quality pool outflow rate, $C_{WQ}$ (cfs)
$Q_{WQ} = (WQv*43,560)/(40*3,600)$ — $Q_{WQ}$ (cfs) = **0.49**

Step 4) V-notch weir coefficient, $C_v$ — $C_v$ = **2.5**

Step 5) V-notch weir angle, θ (deg)
$\theta = 2*(180/\pi)*\arctan(Q_{WQ}/(C_v*H_{WQ}^{5/2}))$
V-notch angle should be at least 20 degrees. Set to 20 degrees if calculated angle is smaller. — θ (deg) = **8**

Step 6) Top width of V-notch weir, $W_v$ (ft)
$W_v = 2*Z_{WQ}*TAN(\theta/2)$ — $W_v$ (ft) = **0.43**

Step 7) To calculate v-notch angle for EDDB with an irregular stage-volume relationship, use the V-notch Weir Worksheet

III. Flood Control

Refer to APWA Secifications Section 5608

IV. Trash Racks

Step 1) Total outlet area, $A_{ot}$ (in$^2$) — $A_{ot}$ (in$^2$) = **21.5**

Step 2) Required trash rack open area, $A_t$ (in$^2$)
$A_t = A_{ot}*77*e^{(-0.124*D)}$ for single orifice outlet
$A_t = (A_{ot}/2)*77*e^{(-0.124*D)}$ for orifice plate outlet
$A_t = 4*A_{ot}$ for v-notch weir outlet — $A_t$ (in$^2$) = **668**

V. Basin Shape

Step 1) Length to width ratio should be at least 3:1 (L:W) wherever practicable — (L:W) = **3.0**

Step 2) Low flow channel side lining — Concrete: **X**; Soil / riprap: __; No low flow channel: __

Step 3) Top stage floor drainage slope (toward low flow channel), $S_{ts}$ (%) — $S_{ts}$ (%) = **2.0**
Top stage depth, $D_{ts}$ (ft) — $D_{ts}$ (ft) = **1.5**

Step 4) Bottom stage volume, $V_{bs}$ (ac-ft) — $V_{bs}$ (% of WQv) = **15%**; $V_{bs}$ (ac-ft) = **0.24**

**Design Procedure Form: Extended Dry Detention Basin (EDDB)**
**Main Worksheet**

**Designer:** ____________ **Date:** ____________
**Checked By:** ____________ **Project:** EXAMPLE
**Company:** ____________ **Location:** ____________
**Page:** 3 of 3

VI. Forebay (Optional)

| | | |
|---|---|---|
| Step 1) Volume should be greater than 10% of WQv | Min $Vol_{FB}$ (ac-ft) = | **0.19** |
| Step 2) Forebay depth, $Z_{FB}$ (ft) | $Z_{FB}$ (ft) = | **1.5** |
| Step 3) Forebay surface area, $A_{FB}$ (ac) | Min $A_{FB}$ (ac) = | **0.13** |
| Step 4) Paved/hard bottom and sides? | | **Yes** |

VII. Basin side slopes

Basin side slopes should be at least 4:1 (H:V) — Side Slope (H:V) = **4.0**

VIII. Dam Embankment side slopes

Dam Embankment side slopes should be at least 3:1 (H:V) — Dam Embankment (H:V) = **3.0**

IX. Vegetation

Check the method of vegetation planted in the EDDB or describe "other"

__ Native Grass
X Irrigated Turf Grass
__ Other: ____________

X. Inlet Protection

Indicate method of inlet protection/energy dissipation at EDDB inlet — **Riprap apron**

XI. Access

Indicate that access has been provided for maintenance vehicles — **Yes**

## Design Procedure Form: Extended Dry Detention Basin (EDDB)

### Main Worksheet

**Designer:** ________________________  **Date:** ________________________
**Checked By:** ________________________  **Project:** ________________________
**Company:** ________________________  **Location:** ________________________
**Page:** 1 of 3

I. Basin Water Quality Storage Volume

Step 1) Tributary area to EDDB, $A_T$ (ac) — $A_T$ (ac) = __________

Step 2) Calculate WQv using methodology in Section 6 — WQv (ac-ft) = __________

Step 3) Add 20 percent to account for silt and sediment deposition in the basin — $V_{design}$ (ac-ft) = __________

IIa. Water Quality Outlet Type

Step 1) Set water quality outlet type — Outlet Type = __________

Type 1 = single orifice
Type 2 = perforated riser or plate
Type 3 = v-notch weir

Step 2) Proceed to Step IIb, IIc, or IId based on water quality outlet type slected

IIb. Water Quality Outlet, Single Orifice

Step 1) Depth of water quality volume at outlet, $Z_{WQ}$ (ft) — $Z_{WQ}$ (ft) = __________

Step 2) Average head of water quality volume over invert of orifice, $H_{WQ}$ (ft)

$H_{WQ} = 0.5 * Z_{WQ}$ — $H_{WQ}$ (ft) = __________

Step 3) Average water quality outflow rate, $Q_{WQ}$ (cfs)

$Q_{WQ} = (WQ_v * 43{,}560)/(40 * 3{,}600)$ — $Q_{WQ}$ (cfs) = __________

Step 4) Set value of orifice discharge coefficient, $C_o$

$C_o$ = 0.66 when thickness of riser/weir plate is ≤ orifice diameter
$C_o$ = 0.80 when thickness of riser/weir plate is > orifice diameter — $C_o$ = __________

Step 5) Water quality otulet orifice diameter (minimum of 4 inches), $D_o$ (in)

$D_o = 12 * 2 * (Q_{WQ}/(C_o * \pi * (2 * g * H)^{0.5}))^{0.5}$ — $D_o$ (in) = __________

(if orifice diameter < 4 inches, us outlet type 2 or 3)

Step 6) To size outlet orifice for EDDB with an irregular stage-volume relationship, use the Single Orifice Worksheet

IIc. Water Quality Outlet, Perforated Riser

Step 1) Depth at outlet above lowest perforation, $Z_{WQ}$ (ft) — $Z_{WQ}$ (ft) = __________

Step 2) Recommended maximum outlet area per row, $A_o$ (in$^2$)

$A_o = (WQv)/(0.013 * Z_{WQ}^2 + 0.22 * Z_{WQ} - 0.10)$ — $A_o$ (in$^2$) = __________

Step 3) Circular perforation diameter per row assuming a single column, $D_1$ (in) — $D_1$ (in) = __________

Step 4) Number of columns, $n_c$ — $n_c$ = __________

Step 5) Design circular perforation diameter (should be between 1 and 2 inches), $D_{perf}$ (in) — $D_{perf}$ (in) = __________

Step 6) Horizontal perforation column spacing when $n_c > 1$, center to center, $S_c$ — $S_c$ (in) = __________

If $D_{perf} \geq 1.0$ inch, $S_c = 4$

Step 7) Number of rows (4" vertical spacing between perforations, center to center), $r_r$ — $n_r$ = __________

**Design Procedure Form: Extended Dry Detention Basin (EDDB)**
**Main Worksheet**

**Designer:** ______________________ **Date:** ______________________
**Checked By:** ______________________ **Project:** ______________________
**Company:** ______________________ **Location:** ______________________
**Page:** __2__ of __3__

IId. Water Quality Outlet, V-notch Weir

Step 1) Depth of water quality volume above permanent pool, $Z_{WQ}$ (ft) — $Z_{WQ}$ (ft) = __________

Step 2) Average head of water quality pool volume over invert of v-notch, $H_{WQ}$ (ft)
$H_{WQ} = 0.5*Z_{WQ}$ — $H_{WQ}$ (ft) = __________

Step 3) Average water quality pool outflow rate, $Q_{WQ}$ (cfs)
$Q_{WQ} = (WQv*43,560)/(40*3,600)$ — $Q_{WQ}$ (cfs) = __________

Step 4) V-notch weir coefficient, $C_v$ — $C_v$ = __________

Step 5) V-notch weir angle, θ (deg)
$\theta = 2*(180/\pi)*\arctan(Q_{WQ}/(C_v*H_{WQ}^{5/2}))$
V-notch angle should be at least 20 degrees. Set to 20 degrees if calculated angle is smaller. — θ (deg) = __________

Step 6) Top width of V-notch weir, $W_v$ (ft)
$W_v = 2*Z_{WQ}*\mathrm{TAN}(\theta/2)$ — $W_v$ (ft) = __________

Step 7) To calculate v-notch angle for EDDB with an irregular stage-volume relationship, use the V-notch Weir Worksheet

III. Flood Control

Refer to APWA Secifications Section 5608

IV. Trash Racks

Step 1) Total outlet area, $A_{ot}$ (in$^2$) — $A_{ot}$ (in$^2$) = __________

Step 2) Required trash rack open area, $A_t$ (in$^2$)
$A_t = A_{ot}*77*e^{(-0.124*D)}$ for single orifice outlet
$A_t = (A_{ot}/2)*77*e^{(-0.124*D)}$ for orifice plate outlet
$A_t = 4*A_{ot}$ for v-notch weir outlet — $A_t$ (in$^2$) = __________

V. Basin Shape

Step 1) Length to width ratio should be at least 3:1 (L:W) wherever practicable — (L:W) = __________

Step 2) Low flow channel side lining — Concrete: __________
Soil / riprap: __________
No low flow channel: __________

Step 3) Top stage floor drainage slope (toward low flow channel), $S_{ts}$ (%) — $S_{ts}$ (%) = __________
Top stage depth, $D_{ts}$ (ft) — $D_{ts}$ (ft) = __________

Step 4) Bottom stage volume, $V_{bs}$ (ac-ft) — $V_{bs}$ (% of WQv) = __________
$V_{bs}$ (ac-ft) = __________

**Design Procedure Form: Extended Dry Detention Basin (EDDB)**
**Main Worksheet**

**Designer:** ______________________ **Date:** ______________________
**Checked By:** ______________________ **Project:** ______________________
**Company:** ______________________ **Location:** ______________________
**Page:** 3 of 3

VI. Forebay (Optional)

Step 1) Volume should be greater than 10% of WQv — Min $Vol_{FB}$ (ac-ft) = __________

Step 2) Forebay depth, $Z_{FB}$ (ft) — $Z_{FB}$ (ft) = __________

Step 3) Forebay surface area, $A_{FB}$ (ac) — Min $A_{FB}$ (ac) = __________

Step 4) Paved/hard bottom and sides? __________

VII. Basin side slopes

Basin side slopes should be at least 4:1 (H:V) — Side Slope (H:V) = __________

VIII. Dam Embankment side slopes

Dam Embankment side slopes should be at least 3:1 (H:V) — Dam Embankment (H:V) = __________

IX. Vegetation

Check the method of vegetation planted in the EDDB or describe "other"

__ Native Grass
__ Irrigated Turf Grass
__ Other: ________________
______________________

X. Inlet Protection

Indicate method of inlet protection/energy dissipation at EDDB inlet __________

XI. Access

Indicate that access has been provided for maintenance vehicles __________

## Variable Dictionary

| Variable | Units | Definition |
|---|---|---|
| $A_{ot}$ | $in^2$ | Total open area of outlet structure |
| $A_{FB}$ | ac | Forebay surface area |
| $A_t$ | $in^2$ | total required trash rack open area |
| $A_T$ | ac | Tributary area to EDDB |
| $C_o$ | none | Orifice discharge coefficient |
| $C_v$ | none | V-Notch weir discharge coefficient |
| $D_o$ | in | Water quality outlet orifice diameter |
| $D_1$ | in | Circular perforation diameter per row, assuming a single column, for perforated riser or weir plate |
| $D_{perf}$ | in | Design circular perforation diameter for perforated riser or weir plate |
| $D_{ts}$ | ft | EDDB top stage depth |
| $H_{WQ}$ | ft | Average head of WQv over invert of water quality outlet |
| $n_c$ | none | Number of columns of perforations for perforated riser or weir plate |
| $n_r$ | none | Number of rows of perforations for perforated riser or weir plate |
| $\theta$ | deg | V-Notch weir angle |
| $Q_{WQ}$ | cfs | Average WQv outflow rate |
| $S_c$ | in | Horizontal perforation column spacing for perforated riser or weir plate |
| $S_{ts}$ | % | Top stage floor drainage slope toward low flow channel |
| $V_{bs}$ | ac-ft | Bottom stage volume |
| $V_{design}$ | ac-ft | Design volume of EDDB, accounts for 20% basin filling with sediment |
| $Vol_{FB}$ | ac-ft | Pre-sedimentation forebay volume |
| WQv | ac-ft | Water quality volume |
| $W_v$ | ft | V-notch weir width |
| $Z_{FB}$ | ft | Forebay depth |
| $Z_{WQ}$ | ft | Depth of WQv above invert of outlet |

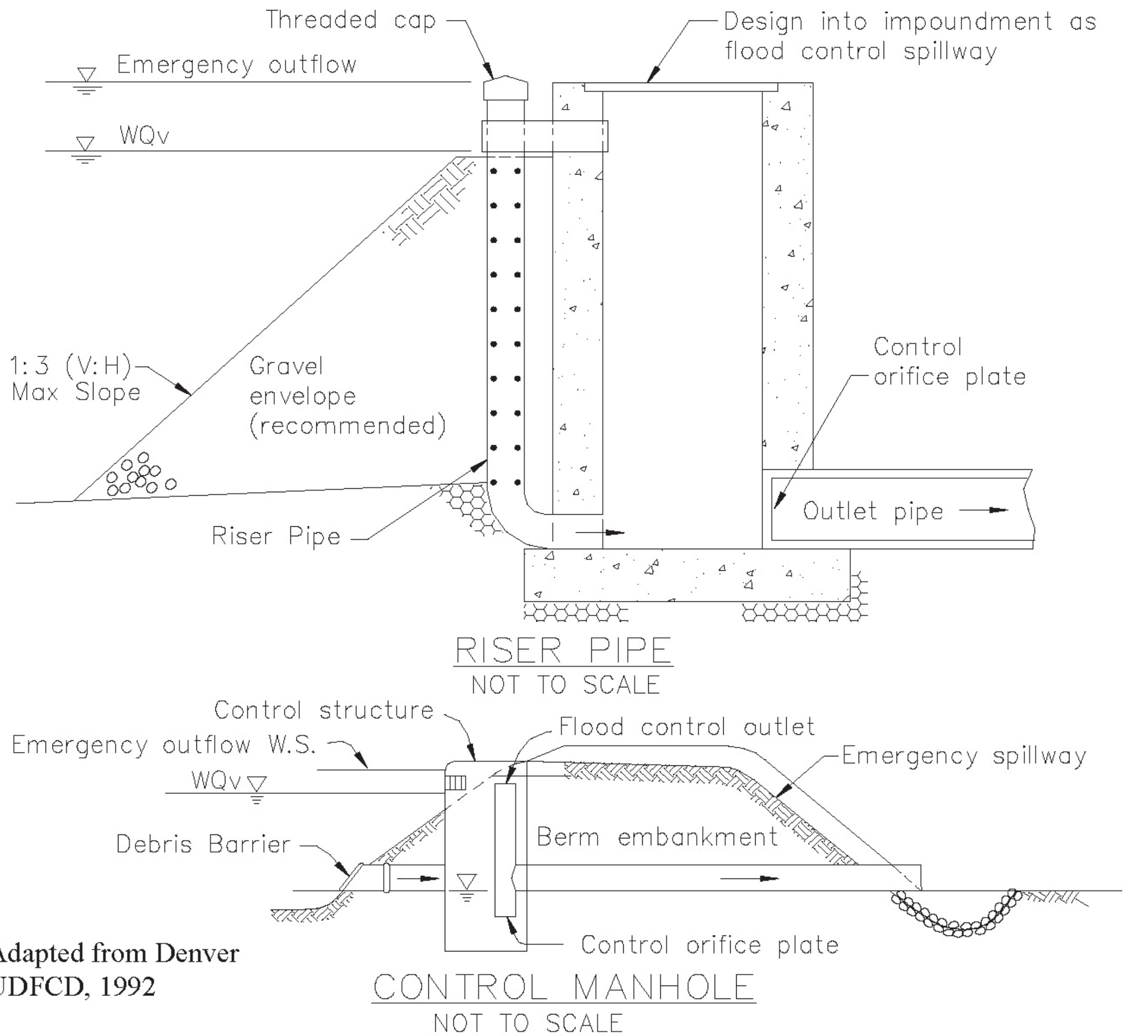
**Part 2b.(v) Water quality outlet orifice diameter derivation from Orifice Equation**

$Q_{WQ} = C_o * A * (2 * g * H)^{0.}$ (Orifice Equation)

$Q_{WQ} = C_o * (\pi * D_o^2/4) * (2 * g * H)^{0.5}$ (Do = orifice diameter in feet)

$D_o = \{4 * Q_{WQ}/[C_o * \pi * (2 * g * H)^{0.5}]\}^{0.5}$ (Solve for Do, in feet)

$D_o = 12 * 2 * \{Q_{WQ}/[C_o * \pi * (2 * g * H)^{0.5}]\}^{0.5}$ (Simplify and convert Do to inches)




Adapted from Denver UDFCD, 1992

Figure 8.23 - Sandpipe Outlet Structure

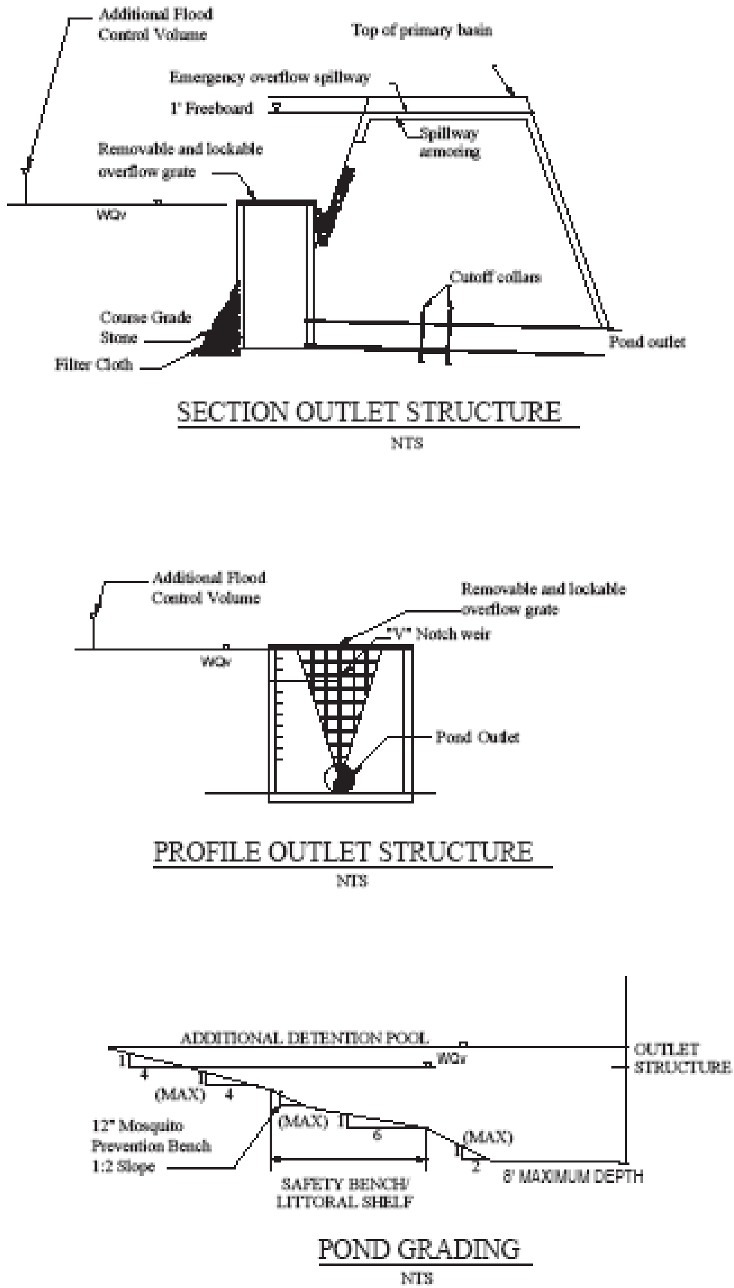
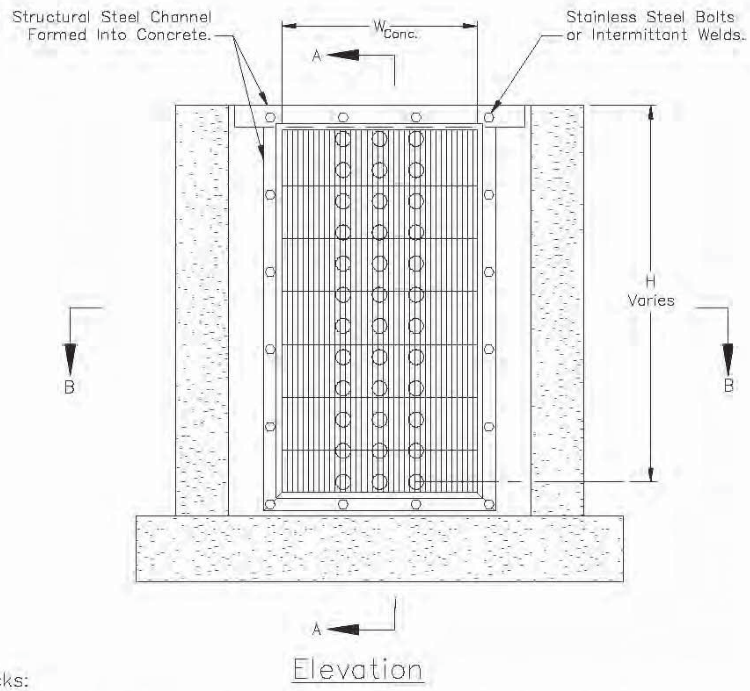



Figure 8.24 - "V" Notch Weir Outlet Structure (3)




WQv Trash Racks:

1. Well–screen trash racks shall be stainless steel and shall be attached by intermittant welds along the edge of the mounting frame.
2. Bar grate trash racks shall be aluminum and shall be bolted using stainless steel hardware.
3. Trash Rack widths are for specified trash rack material. Finer well–screen or mesh size than specified is acceptable, however, trash rack dimensions need to be adjusted for materials having a different open area/gross area ratio (R value)
4. Structural design of trash rack shall be based on full hydrostatic head with zero head downstream of the rack.

Overflow Trash Racks:

1. All trash racks shall be mounted using stainless steel hardware and provided with hinged and lockable or boltable access panels.
2. Trash racks shall be stainless steel, aluminum, or steel. Steel trash racks shall be hot dip galvanized and may be hot powder painted after galvanizing.
3. Trash Racks shall be designed such that the diagonal dimension of each opening is smaller than the diameter of the outlet pipe.
4. Structural design of trash rack shall be based on full hydrostatic head with zero head downstream of the rack.

Adapted from Denver Urban Drainage and Flood Control District

Figure 8.25 - $WQ_V$ Outlet Trash Rack Design (3)

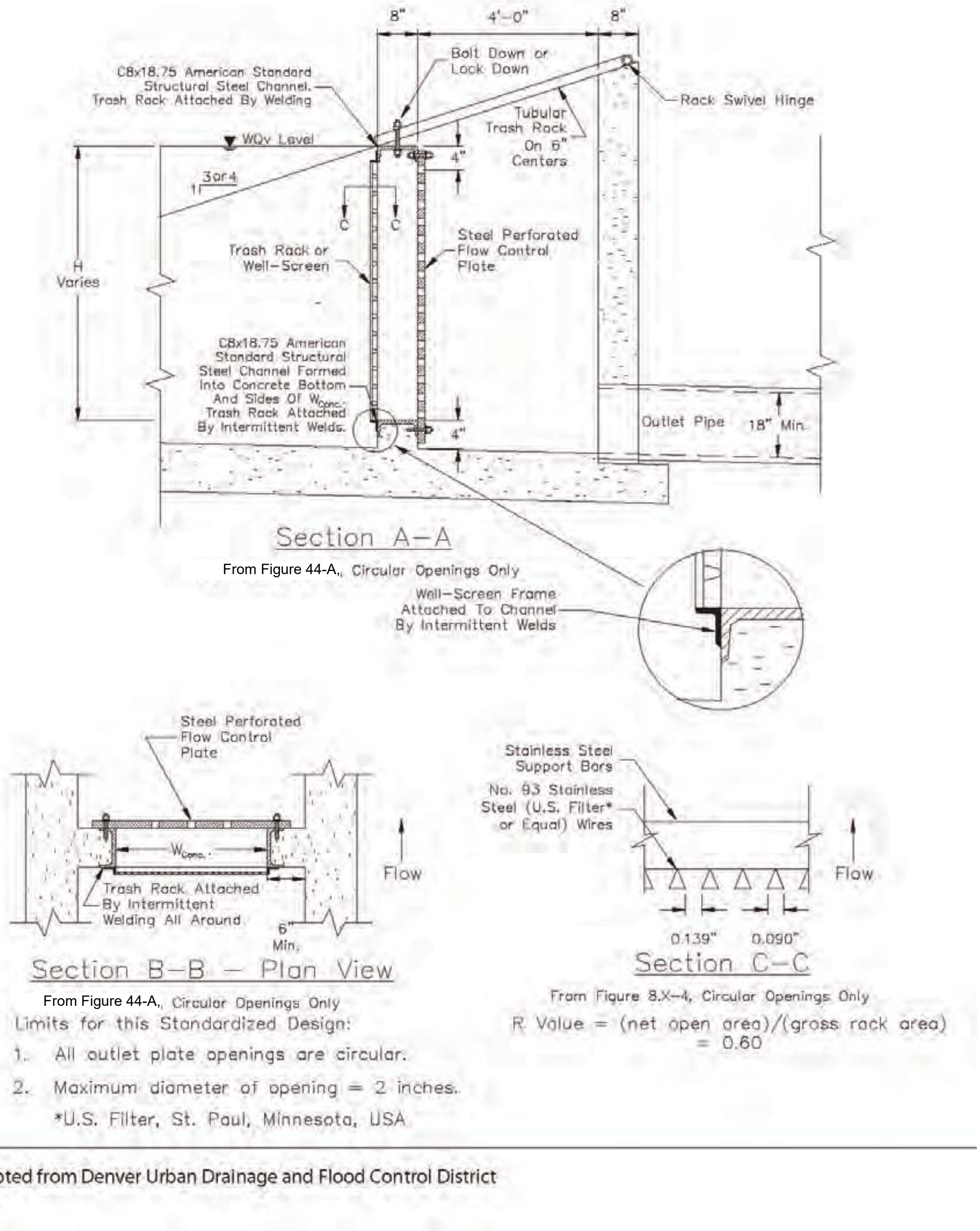



Figure 8.26 - $WQ_V$ Outlet Trash Rack Design (3)

## 8.13 TURF SWALES

### 8.13.1 Description

Turf grass swales are broad, shallow, natural, or constructed channels with a dense stand turf grass covering the side slopes and channel bottom. They slowly convey stormwater runoff, and in the process promote infiltration,, reduce flow velocities, and pretreat stormwater. Turf swales can have either parabolic or trapezoidal cross sections. Turf grass swales are intended to be used as a substitute for traditional pipe systems to treat and convey roadway drainage.

### 8.13.2 General Application


Picture Source: Olsson Associates

**Targeted Constituents**

| Constituent | Removal Effectiveness |
|---|---|
| Sediment | High |
| Nutrients | Medium |
| Trash | Low |
| Metals | Medium |
| Bacteria | Medium |
| Oil and Grease | Low |
| Organics | Medium |

Legend (Removal Effectiveness): High ● Medium ◐ Low ○

Rather than routing stormwater runoff into a lined channel or into a curb-gutter system, consider using a natural conveyance channel. Turf swales promote infiltration and also help settle many particulate contaminants. Do not use channels as a BMP component to convey deep concentrated flow; channels are only effective conveying shallow concentrated flow. Take care to identify the proper location for a Turf swale. Minimizing disturbance to the area (for example, avoiding application of pesticides and herbicides) maintains the channel's ability to remove contaminants. Select grass species that tolerate frequent inundation.

### 8.13.3 Advantages

- Constructed less expensively and maintained more easily than underground pipes
- Improve water quality by infiltration, sedimentation and biological uptake
- Reduce total volume of runoff to surrounding streams and rivers
- Minimize erosion by slowing the conveyance of water.

### 8.13.4 Disadvantages

- May require irrigation to maintain proper vegetative cover for controlling erosion and reducing pollution in the channel
- May not be feasible to implement after development has occurred
- Require relatively large areas, proper sloping, and connection with other conveyance components

- Not designed to be the fastest conveyance method and, therefore, require exact placement and design to minimize risk of flooding.

## 8.13.5 Design Considerations

***Source***: Metropolitan Council Environmental Services. 2001 *Minnesota Urban Small Sites BMP Manual,* St. Paul, MN.

The design approach for sizing turf swales is based on conveying the water quality flow at a shallow depth (<4"). This methodology incorporates a flowrate-based sizing criteria for the water quality, 1%, and 10% frequency storm. Provide bypass for high flows if the swale cannot be stable during the 10% or greater storm.

The following design specifications are summarized in Table 8.9.

Table 8.9
Design Summary for Turf Swales

| Parameter | Swale Design Criteria |
|---|---|
| Energy Dissipation | Required if incoming flow is piped |
| Side Slopes | 4:1 recommended; 3:1 maximum |
| Longitudinal Slope | 1-2%, velocity for 50% storm must not exceed erosive velocity for turf. |
| Underlying soil bed | Undisturbed soils equal to the swale width. No underdrain system. |
| Drainage Area | 5 acres or less |
| Depth | $WQ_f$ depth of 4 inches or less. |
| Flow Velocity | < 1 fps for WQ event; 4 fps for 2-yr storm |
| Minimum Swale Length | Length based on a 5 minute residence time, or 100 feet, whichever is greater. |
| Bottom Width | 2-feet minimum; 6-feet maximum |
| Manning's "n" | 0.15 for water quality treatment (depth < 4 inches); varies from 0.15 – 0.03 for depths of 4 to 12 inches; 0.03 minimum for depths > 12 inches |

### *8.13.5.1 Shape and Slope*

- The swales should generally be trapezoidal in shape, although a parabolic shape is also acceptable (provided the width is equal to or greater than the design bottom width for a trapezoidal cross section). The criteria presented in this section assume a trapezoidal cross section.
- For the trapezoidal cross section, size of the bottom width between two and six feet. The two feet minimum allows for construction considerations and ensures a minimum filtering surface for water quality treatment. The six feet maximum reduces the likelihood of flow channelization within a portion of the swale.
- The side slopes of the channel should be no steeper than 3:1 for maintenance and safety considerations. Flatter slopes are encouraged where adequate space is available to aid in providing pretreatment for lateral flows.
- The longitudinal slope of the swale should be moderately flat to provide the slowest flow rate possible. When natural topography necessitates, steeper slopes may be acceptable if check dams (vertical drops of 6 to 12 inches) are used. These structures will require additional energy dissipating measures and should be placed no closer than 50 to 100 foot interval.

## 8.13.6 Design Size and Soils

Source: Metropolitan Council Environmental Services. 2001 Minnesota Urban Small Sites BMP Manual, St. Paul, MN.

- Design swales to provide a shallow flow depth for the water quality storm (a maximum of 4 inches for the water quality flow is recommended), safely convey the 2 year storm with design velocities appropriate for the soil and cover types, and provide adequate capacity for the 10 year and 100 year storm with a minimum of 1 foot of freeboard if applicable.
- See that the soil bed below the swale consists of undisturbed soils. This area may be periodically inundated and remain wet for long periods of time.
- Do no construct turf swales in gravelly and coarse sandy soils that cannot easily support dense vegetation.
- In areas with steep slopes, employ turf swales in locations where they can be parallel to the contours.
- Size channels to convey the 10 and 100-year storm volumes and design channel slopes to prevent erosion during the 2-year storm events.
- Use outlet protection at any discharge point from turf swales to prevent scour at the outlet.
- Provide minimum freeboard above 100-year storm water surface profile (1.0 foot minimum or as required by local ordinance.
- Identify the swale bottom, width, depth, length, and slope necessary to convey the water quality flow rate with a shallow depth (approximate maximum of 4 inches).
- Compute the 2-year, 10-year, and 100-year frequency storm event peak discharges.
- Check the 10-year and 100-year velocity for erosive potential (adjust swale geometry, if necessary reevaluate WQv design parameters).
- Provide pretreatment to protect the filtering and infiltration capacity of the swale bed. Pretreatment can occur in a sediment forebay behind a check dam with a pipe inlet.
- Use check dams in turf swales to achieve flatter sections with slower velocities. V-notched weirs in the check dams can be utilized to direct flow and volumes.
- Design turf swales with trapezoidal or parabolic cross sections, and with side slopes no greater than 3:1 (horizontal:vertical) and bottom widths ranging from 2 to 6 feet.
- Check permissible velocities of selected vegetation to ensure the 2-year frequency storm is non-erosive.

### *8.13.6.1 Vegetative Cover*

Source: Metropolitan Council Environmental Services. 2001 Minnesota Urban Small Sites BMP Manual, St. Paul, MN.

- Grass species selection will depend upon the duration of water inundation, soil type, and amount of light.
- Specify grass species resistant to periodic inundation and periodic drought
- Appropriate soil stabilization methods, such as mulch, blankets or mats should be used before the establishment of vegetation. Seeding, sodding, and other items related to establishing vegetation should be in accordance with accepted erosion-control and planning practices.

## 8.13.7 Maintenance and Inspections

Source: Metropolitan Council Environmental Services. 2001 Minnesota Urban Small Sites BMP Manual, St. Paul, MN.

The following is a partial list of actions to upkeep turf swales:

- Inspect swale several times the first few months to ensure plant species are establishing well. If not, reseed or plant an alternative species. Also, inspect the channel for erosion after every rainfall event and repair as necessary.
- If a forebay is used, inspect and remove excessive sediment, trash, and debris and dispose of in an appropriate location.
- Control vegetation by mowing or grubbing techniques (not by chemicals).
- If heavy sediment loading occurs, clean the channel to remove excess particulates.

## 8.13.8 Design Example

### *8.13.8.1 Calculations*

Step 1 - Find peak flowrate (Q) for tributary area to swale for water quality rainfall event using Rational Method.

$$Q_{WQ} = K \cdot C \cdot i \cdot A$$

Where:

Q = Peak flowrate of runoff (cfs)

C = Runoff Coefficient = 0.3 + 0.6 × I, where I is percent impervious divided by 100

I = Rainfall intensity for water quality rainfall event at the duration equal to the calculated time of concentration (inches/hr) from Section 6.

A =Tributary drainage area (acres)

K =Dimensionless coefficient to account for antecedent precipitation

1.0 for the Water Quality Storm

Step 2 - Solve Manning's equation for a specified variable. For this example, we will calculate flowrate at the maximum allowable depth to verify the swale can carry the proposed peak flowrate. This step is most easily accomplished using a spreadsheet or solver program.

Step 3 - Solve V = Q/A for velocity using calculated variable and Q calculated in Step 1. If V is greater than 1 ft/s, the width of channel, longitudinal slope of channel, or Manning's n value may need to be adjusted to obtain a velocity less than 1 fps, and therefore appropriate for shallow flow.

Step 4 - Solve for minimum swale length: L = V x 5 min x 60 sec/min. Minimum 100 feet.

Step 5 - Find peak flowrate (Q) for tributary area to swale for the 50% rainfall event using Rational Method.

Step 6 - Solve V = Q/A for velocity using calculated area and Q calculated in Step 4. If V is greater than 4 ft/s, the shape of channel or longitudinal slope of channel may need to be adjusted to obtain a non-erosive velocity less than 4 fps.

Note that an agency may require that a swale also be designed for conveyance of a defined design storm (e.g. 10% or 1% storm event). Additional calculations may be necessary to size the swale for other larger events.

### *8.13.8.2 Design Example*

A 5.0 acre site is being developed by a church (C=0.75) in the Kansas City Metro. 0.25 acres of the site will be tributary to a proposed 4-foot turf swale, with a Manning's n value of 0.03 and side slopes at 5:1. Assume a time of concentration of 10 minutes to the swale. Proposed longitudinal slope is 2.0-percent. Design the swale for the water quality rainfall event.

Step 1 - Calculate the water quality rainfall event Q using the Rational Method. Methodology can be found in Section 6 of this manual.

Q = (1.0)*(0.75)*(1.68 in/hr)*(0.25acre) = 0.32 cfs

Step 2 - Using a solver program, depth in the swale was calculated for the peak Water Quality flow using Manning's equation.

Trapezoidal (5:1) Swale Example

| n value | Iterated Depth (D) feet | Width (W) feet | Area (A) ($ft^2$) | Wetted Perimeter (ft) | Hydraulic Radius ($R_h$) (ft) | Longitudinal Slope (ft/ft) | Q (CFS) |
|---|---|---|---|---|---|---|---|
| 0.03 | 0.06 | 5.50 | 0.32 | 6.07 | 0.053 | 0.02 | 0.32 |

The proposed swale can carry the Water Quality peak flow of 0.32 cfs below the maximum 4-inch depth.

Step 3 - Calculate Velocity.

V = (0.32 cfs)/(0.32 $ft^2$) = 1.0 ft/s. Therefore the proposed swale meets recommendations for the Water Quality Storm.

Step 4 - Calculate Length

V = 1 ft/s x 5 min x 60 sec/min = 300 ft

Step 5 - Calculate the 50% rainfall event Q using the Rational Method. Methodology can be found in APWA 5602.

Q =(1.0)* (0.75)*(4.30 in/hr)*(0.25acre) = 0.81 cfs

Step 6 - Using a solver program, 50% storm event flow depth and area in the swale were calculated using Manning's equation.

Trapezoidal (5:1) Swale Example

| n value | Depth (D) feet | Width (W) feet | Iterated Area (A) $ft^2$ | Wetted Perimeter (ft) | Hydraulic Radius($H_R$) (ft) | Long Slope (ft/ft) | Q (CFS) |
|---|---|---|---|---|---|---|---|
| 0.03 | 0.10 | 5.50 | 0.58 | 6.49 | 0.89 | 0.02 | 0.81 |

V = (0.81 cfs)/(0.58 $ft^2$) = 1.40 ft/s. This is less than 4 ft/s, and therefore meets recommendations for non-erosive velocities.

## 8.14 PROPRIETARY MEDIA FILTRATION

Picture Source: CONTECH Stormwater Solutions Inc.

**Targeted Constituents**

| Constituent | Removal Effectiveness |
|---|---|
| Sediment | High |
| Nutrients | Medium |
| Trash | High |
| Metals | High |
| Bacteria | Medium |
| Oil and Grease | High |
| Organics | High |

Legend (Removal Effectiveness): High, Medium, Low

### 8.14.1 Description

Proprietary media filtration systems are available in a number of configurations and designs, but all remove pollutants from stormwater by directing the runoff flow through a bed of media. This media may be chemically inert, targeting suspended solids particles and associated particulate pollutants, or may utilize ion exchange or other sorption processes to remove dissolved pollutant constituents.

### 8.14.2 General Application

As state and local regulations increase pollutant removal requirements for BMPs, media filtration systems have emerged among the highest performing proprietary processes for stormwater treatment. These systems are available from a variety of manufacturers and can be designed to address most of the common pollutants associated with stormwater runoff. Typically, the filtration media is housed in some standardized unit such as a cartridge or pack, allowing a modular configuration which simplifies system sizing.

Media filtration systems often utilize sedimentation as an integrated pre-treatment process. Heavier particles settle out on the floor of the system and do not contribute to loading of the filter surface. Such devices should be placed in an offline configuration such that flows exceeding system design are diverted and do not cause resuspension of settled material.

There are various types of media that can be used for filtration. Media are often selected to address specific types of pollutants. In many cases a media blend is ideal for general purpose treatment.

- Inert Media - provide treatment for sediment and associated pollutants. There is no chemical process that takes place. Perlite and sand are common examples of inert media. Straining and sedimentation within the media volume are the primary mechanisms of removal as water is forced to take a tortuous path through the media bed. Media gradation is a key variable in inert filters, with finer media able to remove smaller particles. However, a corresponding increase in head loss typically results in lower flow rates through finely graded media.
- Active Media – utilize chemical processes such as ion exchange, adsorption, and absorption to remove dissolved constituents such as metals or nutrients at the molecular level. Active media include zeolite, leaf compost, peat, activated alumina, synthetic resins, and granular activated carbon (GAC). These media are selective in terms of the pollutants they remove, and careful consideration must be taken in pairing media

with the target pollutant. When designing systems with active media, hydraulic treatment capacity is dependent on the contact time required for the respective chemical process.

TABLE 8.10
Pollutant Groups Targeted by Common Media Types

| | Perlite | Leaf Compost or Peat | Zeolite | GAC |
|---|---|---|---|---|
| **Sediments** | ● | ● | | |
| **Oil & Grease** | ● | ● | | |
| **Soluble Metals** | | ● | ● | |
| **Organics** | | ● | | ● |
| **Nutrients** | ● | | ● | |

### 8.14.3 Advantages

- Media filters are a highly versatile type of treatment device and can provide very high level of treatment for most common stormwater pollutants.
- Media filters can typically be configured in underground vaults, allowing improved site usage when compared to above-ground systems.
- Modular system designs can accommodate a variety of applications and can be sized for stand-alone treatment, or as part of a treatment trains. This design flexibility also allows system sizing to accommodate very large and very small treatment areas.
- When configured with specialized media, filter systems are able to remove high levels of dissolved pollutants typically not treated by traditional BMPs.

### 8.14.4 Disadvantages

- Where land costs are moderate, systems typically are more expensive than traditional, above-ground systems.
- Like all proprietary BMPs, the design of these systems is specific to the manufacturer. As such, approval should be subject to performance verification, where possible in field conditions.
- Maintenance costs and requirements may vary greatly, adding to the initial systems cost.

### 8.14.5 Siting and Design Considerations

While manufacturers' designs differ, filter configurations can be evaluated by comparing fundamental parameters between different types of filters. These parameters relate to the velocity and residence time of water through the filter media as well as the pollutant loading capacity of the filter unit.

- Specific Flow Rate – Surface Area (flow/media surface area):The flow rate per unit area of media surface area is important because the surface of the media can become occluded before the entire volume of media is exhausted. Ensuring there is adequate surface area for the design flow is a key parameter to ensure longevity.
- Specific Flow Rate – Media Volume (flow/media volume):Eventually, all of the open area within the media will collect pollutants. Once full, the flow rate will decrease and the system will operate below hydraulic

design. The flow rate per unit volume of media is a measure of performance and longevity – lower specific flow rates imply greater longevity.

- Percent Open Area: Typically there is a "screen" to hold the media within the filter unit (often a cartridge or module). The open area of the "screen" is important to prevent fouling the media surface area. The actual open area of a filter is determined by multiplying the total filter surface area by the percent open area. Systems with larger actual open areas will be less likely to fail due to surface fouling.
- Loading (mass/volume): Every filter can hold a certain amount of sediment and pollutants before the flow rate at a given head begins to decrease. Data from loading tests should be available to provide mass-loading based sizing. This data will provide the information required to ensure the system will operate at design flow rates for the desired maintenance interval.

### 8.14.6 Maintenance

Manufacturers will specify maintenance guidelines and procedures for their respective systems. Typically, media filters are designed for an annualized maintenance cycle, but filter longevity is site-dependant and difficult to predict. There are, however, several important design elements that can provide an indication of maintenance and longevity.

- Surface Cleaning – prolongs the longevity of filter systems by maintaining the percent open area. Siphon-actuated media filters have demonstrated the ability to passively clean the surface of the filter with hydraulic turbulence cased by air bubbles which are created when the siphon breaks. Backflush mechanisms also provide surface cleaning.
- "Dry" Media – it is important the media is above any permanent pool that may exist between storms. This significantly reduces the chance that biological growth will occlude the media and shorten the maintenance interval.
- Dry Sump – some media filters may have a sump located below the cartridges. It is important that the sump is able to drain completely between storms. This reduces the volume of water to be disposed of after maintenance. It also prevents captured organic material from decomposing and washing though the system, as well as providing some vector control.

### 8.14.7 Design Example

Design of proprietary media filtration systems must be completed by the manufacturer.

## 8.15 HYDRO DYNAMIC SEPARATION

Picture Source: CONTECH Stormwater Solutions Inc.

**Targeted Constituents**

| | |
|---|---|
| Sediment | ◐ |
| Nutrients | ○ |
| Trash | ● |
| Metals | ○ |
| Bacteria | ○ |
| Oil and Grease | ● |
| Organics | ○ |

Legend (Removal Effectiveness)

| High | Medium | Low |
|---|---|---|
| ● | ◐ | ○ |

### 8.15.1 Description

Hydrodynamic separators, also known as swirl concentrators or vortex separators, describe a wide variety of proprietary devices that have been developed in recent years. They are modifications of traditional oil/particle separators that typically target coarse solids and large oil droplets. While most of these systems utilize vortex-enhanced sedimentation, others use circular screening systems or engineered cylindrical sedimentation.[1] Vortex separation was originally developed for use in combined sewer overflows.

### 8.15.2 General Application

Hydrodynamic separators are typically used for water quality enhancement in urban and ultra-urban areas where surface BMPs are not feasible. Most are flow-through structures in that the design rate of flow into the structure is regulated by the inflow pipe or structure hydraulics as opposed to BMPs designed to store the entire water quality volume.2

These systems differ from traditional wet vaults in that the primary separation chamber is round rather than rectangular, forcing water to move in a circular fashion. Use of a circular flow path instead of straight line makes it possible to obtain significant removal of suspended sediments and attached pollutants with less space required.3 Additionally, secondary flow paths caused by a friction-induced pressure differential between the surface and bottom of the separator aid in increasing the path length and settling opportunity of entrained particles.4 Oil, grease, and floatable trash and debris collect at the surface of the separator.

Most hydrodynamic separation systems available in an on-line configuration utilize a diversion weir or other flow control structure to facilitate internal bypass of flows that exceed system design capacity. These structures are configured to minimize turbulence within the primary separation chamber in order to prevent trapped sediment from becoming resuspended.

### 8.15.3 Advantages

- Hydrodynamic separators can provide effective removal of coarse particles in less space and at less cost than traditional wet or dry basins.
- These systems can provide effective sediment removal over a wide range of flow conditions.

- Small footprint requirement for installation makes hydrodynamic separators particularly suitable in retrofit applications, particularly in highly developed areas.[1]
- Maintenance costs and requirements are typically less than with traditional settling basins.
- When used as pretreatment in treatment train applications, hydrodynamic separators can prolong the maintenance interval of downstream systems.

### 8.15.4 Disadvantages

- Hydrodynamic separators do not remove dissolved pollutants.
- Regular maintenance is required to avoid resuspension of trapped pollutants.
- Systems that have standing pools of water between storms may cause some level of concern about mosquito breeding.[3]
- These systems do not effectively remove fine particles (on the order of 50 microns in diameter and less).

### 8.15.5 Siting and Design Considerations

Design and subsequent performance expectations differ from manufacturer to manufacturer, but the following design considerations hold for most hydrodynamic separators that are currently available.

- Hydrodynamic separators should be used in an off-line configuration where conditions permit. An upstream diversion structure should be installed to bypass around the unit those flows that exceed the system design capacity.
- When off-line configurations are not possible, care should be taken to distinguish between system treatment capacity and system hydraulic capacity. Failure to recognize the difference may lead to significant undersizing of the system.3 Undersized systems placed in an in-line configuration may be unable to convey peak flows internally without causing resuspension of settled material.
- Headloss differs with the product and the model but is generally on the order of one foot or less.3
- Like all proprietary BMPs, the design of these systems is specific to the manufacturer. As such, approval should be subject to performance verification, where possible in field conditions.
- When treatment goals are measured in terms of TSS removal, a target particle size should be identified to assist in separator sizing. Most manufacturers base their performance claims on laboratory testing with sediment of a specified particle size distribution.

### 8.15.6 Maintenance

- Maintenance of hydrodynamic separators consists of the removal of trapped material with a vacuum truck. As such, these systems should be installed in locations accessible to such equipment.
- Typical maintenance interval is one year; however, site-specific experience may indicate the need for more or less frequent maintenance.[3]
- Design plans for hydrodynamic separators should include inspection and maintenance requirements and schedules.[1]

### 8.15.7 Design Example

Design specifications for hydrodynamic separators depend on the particular device and must be completed by the manufacturer.

## 8.16 CATCH BASIN INSERTS

Picture Source: CONTECH Stormwater Solutions Inc. and Interstate Products, Inc.

**Targeted Constituents**

| | |
|---|---|
| Sediment | ● |
| Nutrients | ○ |
| Trash | ● |
| Metals | ○ |
| Bacteria | ○ |
| Oil and Grease | ● |
| Organics | ○ |

Legend (Removal Effectiveness)

| High | Medium | Low |
|---|---|---|
| ● | ◐ | ○ |

### 8.16.1 Description

Catch Basin Inserts (CBIs) are manufactured filters or fabrics designed to remove trash, debris, and coarse sediment from stormwater runoff directly at the storm drain inlet structure. Some CBIs may also be fabricated to absorb oils. Typically, CBIs are installed beneath a catch basin inlet grate by mounting directly to the structure wall or by suspension from the lip of the inlet.

### 8.16.2 General Application

CBIs can be used to improve the quality of urban runoff coming from roads, parking lots, residential neighborhoods, commercial areas, and industrial sites, and are often considered a relatively inexpensive option for retrofit applications. CBIs are typically not applicable as a stand-alone treatment option. They are best used in conjunction with other BMPs where they can reduce the loading to and increase the maintenance of downstream applications such as media filtration and infiltration.

The most basic CBIs consist of a bag or sock of polypropylene intended for vertical drain inlets. Other types consist of a box constructed of plastic or wire mesh which acts as a frame for manufactured fabrics. Some CBIs are equipped with a type of filter media used to target specific pollutants (i.e. activated carbon, porous polymer, or treated cellulose). Manufacturers' specifications should be closely compared and adhered to for on-site application.

### 8.16.3 Advantages

- Catch Basin Inserts are among the least expensive proprietary BMPs, with initial costs of individual inserts ranging from less than $100 to about $2,000.[1]
- CBIs do not require additional space considerations as storm drain inlet structures are already a component of standard drainage systems.[1]
- CBIs are typically visible from the surface, allowing easy inspection and maintenance.
- When properly maintained, CBIs are an effective means of preventing organic and vegetative debris from entering the storm drain system, where these pollutants often decompose to release soluble nutrient species.

### 8.16.4 Disadvantages

- Sediments tend to blind or clog the fabric or filter media of the Catch Basin Insert, making this type of BMP very maintenance-intensive.[2] These problems may be compounded by street sanding or heavy vegetation.
- Under high runoff rates, CBIs may perform ineffectively or even release pollutants to the drainage system due to very short contact times and potential for flushing previously trapped materials.[3]
- Frequent maintenance and/or replacement needs may offset the initial low costs of these BMPs.

### 8.16.5 Siting and Design Considerations

The following guidelines should be considered when applying Catch Basin Inserts:

- CBIs have a limited ability to remove stormwater pollutants and should not be used as a stand-alone device.
- Two outlets should typically be designed into the device—one for treated stormwater flows, and a second for stormwater flows that exceed the capacity of the device.[3]
- CBIs are most effective at capturing coarse sediment and debris associated with unpaved areas.[4]
- CBIs are not generally effective at capturing metals or pollutants associated with silt- or clay-sized particles.[4]
- Inserts designed to absorb oil and grease have been found to effectively reduce these concentrations when newly installed; however, after some use, the effective reduction capacity has been found to drop considerably.[4]
- Due to the number and variety of CBIs commercially available, design and installation information should be obtained by the manufacturer to ensure optimal treatment of targeted pollutants.
- CBIs should be sited to avoid pooling of water in or around the storm drain inlet structure to avoid the breeding of mosquitoes and other potentially disease-carrying vectors.
- For CBIs equipped with filtration media, the bottom of the media unit should be installed above the level of normal stormwater flow to avoid submerging the media and creating anoxic conditions within the unit. If the media is above the crown of the outlet pipe, it is assumed to be above the normal level of flow.[2]

### 8.16.6 Maintenance and Inspections

Routine maintenance activity is necessary to ensure the effectiveness of CBIs. The most typical cause of CBI malfunction is clogging due to excessive loading of sediment or vegetative matter. CBI clogging can lead to loss of incoming sediment, release of captured pollutants due to flushing, or creation of mosquito and other vector habitats due to pooling.

As CBI design varies greatly across manufacturers, newly-installed systems should be inspected after experiencing two to three heavy storm events in order to assess functionality and ensuing maintenance frequency.

Typical maintenance activities include:

- Frequent inspection of CBI units. When several units are installed at a given site, it should be noted that the maintenance cycle for each unit may vary.
- Remove accumulated trash and debris as needed.
- Maintain good housekeeping practices with landscaping and vegetation such as bagging fallen leaves and sweeping up grass clippings and bud shatter to avoid excess loading to the CBI.
- Inspect CBI during rainfall events to assess applicability of the specific unit to site stormwater flows. Observation of frequent bypass may indicate a misapplication.

- Replace CBIs when sediment loading causes clogging of the system. For CBIs intended to absorb oil, inspect treated water for sheen or other signs that the unit's absorption capacity has been exceeded.
- Follow any additional maintenance recommendations given by the manufacturer.

### 8.16.7 Design Example

Design of catch basin inserts must be completed by the manufacturer.

## 8.17 BAFFLE BOXES & OIL/GRIT SEPARATORS

Picture Source: ADS/Hancor Inc.Inc.

**Targeted Constituents**

| | |
|---|---|
| Sediment | ◐ |
| Nutrients | ○ |
| Trash | ● |
| Metals | ○ |
| Bacteria | ○ |
| Oil and Grease | ◐ |
| Organics | ○ |

Legend (Removal Effectiveness)

| High | Medium | Low |
|---|---|---|
| ● | ◐ | ○ |

### 8.17.1 Description

Baffle Boxes, also known as Oil/Grit Separators describe a wide variety of proprietary devices that have been developed in recent years. They are modifications of traditional oil/particle separators that typically target coarse solids and large oil droplets. These systems utilize proven technology of particle separation using Stoke's Law principles, and a standard orifice equation. Most of these systems are installed in an offline configuration, treating the "first flush" from a storm event by utilizing a bypass structure to divert the first flush into the treatment unit.

### 8.17.2 General Application

Baffle Boxes and Oil/Grit separators are typically used for water quality enhancement in urban and ultra-urban areas where surface BMPs are not feasible. They are also commonly used as pre-treatment for surface BMP's where a treatment train is necessary to accomplish water quality goals. Most are flow-through structures in that the design rate of flow into the structure is regulated by the bypass structure as opposed to BMPs designed to store the entire water quality volume.

These systems typically have a sediment chamber that is sized based on Stoke's Law principles, and a chamber for floatables and hydrocarbon trapping. Normally, these systems operate on the principles of "first flush" treatment which provides the ability for larger storms to flow around the unit without re-suspending particles, which have already been trapped. This provides for retention of the particles even during very large storms, without the fear of re-suspension. Oil, grease, and floatable trash and debris collect at the surface of the separator. The floating material is prevented from leaving the unit by a system of baffles and weirs.

Most baffle boxes and Oil/Grit separators utilize a bypass structure or other flow control structure to direct the "first flush" into the treatment unit. Flows that exceed the treatment capacity of the unit are bypassed in the existing storm sewer.

### 8.17.3 Advantages

- This new generation of Baffle Boxes and Oil/Grit Separators provide effective removal of particles as small as 100 microns in less space and at less cost than traditional wet or dry basins.
- These systems also provide effective removal of Hydrocarbons and floatables in storm sewer effluent.
- Shallow installation depths allow for ease of installation. They are installed parallel to existing storm sewers, which makes baffle boxes and oil/grit separators particularly suitable in retrofit applications, particularly in highly developed areas.
- Maintenance costs and requirements are typically less than with traditional settling basins.
- When used as pretreatment in treatment train applications, these systems can prolong the maintenance interval of downstream systems.

### 8.17.4 Disadvantages

- Dissolved pollutants are not treated by these systems.
- Regular maintenance is required to assure proper operation of the system.
- Systems that have standing pools of water between storms may cause some level of concern about mosquito breeding.[3]
- These systems do not effectively remove fine particles (on the order of 50 microns in diameter and less).

### 8.17.5 Siting and Design Considerations

Design and subsequent performance expectations differ from manufacturer to manufacturer, but the following design considerations hold for most baffle boxes and oil/grit separators that are currently available:

- Since these systems operate in a bypass configuration, care should be taken to make sure that proper fall in the bypass line exists in order to be able to tie the treated line back into the main line. Failure to take this into consideration, or to request a weir at the bypass, will result in improper hydraulics, and difficult field adjustments.
- Depending on the size of the unit specified, they can have a relatively large horizontal footprint. Care should be taken to make sure adequate room is provided to allow for proper installation.
- Headloss differs with the product and the model but is generally on the order of one foot or less.
- Like all proprietary BMPs, the design of these systems is specific to the manufacturer. As such, approval should be subject to performance verification. Third party performance testing should be requested by design engineer.
- When treatment goals are measured in terms of TSS removal, a target particle size should be identified to assist in separator sizing. Most manufacturers base their performance claims on laboratory testing with sediment of a specified particle size distribution.

### 8.17.6 Maintenance

- Maintenance of Baffle Boxes & Oil Grit Separators consists of the removal of trapped material with a vacuum truck. As such, these systems should be installed in locations accessible to such equipment.
- Typical maintenance interval is one year; however, site-specific experience may indicate the need for more or less frequent maintenance.
- Design plans for these systems should include inspection and maintenance requirements and schedules.

### 8.17.7 Design Example

Design specifications for Baffle Box depend on the particular device and must be completed by the manufacturer.

## 8.18 VEGETATED FILTER STRIP

### 8.18.1 Description

Vegetated filter strips are uniformly graded and densely vegetated sections of land, engineered and designed to treat runoff and remove pollutants through vegetative filtering and infiltration. Filter strips are best suited to treating runoff from roads, roof downspouts, small parking lots, and pervious surfaces. They are also ideal components of the "outer zone" of a stream corridor (outer 1/3rd), or as pretreatment for another structural stormwater control. Filter strips rely on the use of vegetation to slow runoff velocities and filter out sediment and other pollutants from urban stormwater. To be effective, sheet flow must be maintained across the entire filter strip.

### 8.18.2 Design Requirements and Considerations

Vegetated filter strips shall be designed to meet the following requirements:

#### *8.18.2.1 Entrance Flow*

Flow must enter and exit the filter strip as sheet flow spread out over the width (long dimension perpendicular to flow) of the strip. For runoff from impervious areas, flow spreaders such as concrete sills, curb stops, curb cuts, or pea gravel diaphragms (gravel-filled trench) shall be incorporated along the upstream length of the VFS.

#### *8.18.2.2 Sizing*

The filter strip length shall be properly sized in order to provide adequate filtration and contact time for water quality treatment. The following requirements shall apply to the design of vegetated filter strips (see Figure 8.27):

- Maximum effective inflow approach length (area tributary to VFS) shall be 130 feet. Effective inflow length ($L_a$) shall be calculated as follows:

  $L_a = P_L + 2*I_L$

Where:

$P_L$ = pervious area flow length

$I_L$ = impervious area flow length

- VFS length (measured in the direction of flow through VFS) shall be equal to one third (1/3) of the effective inflow approach length ($L_a$) with a minimum of ten (10) feet.

#### *8.18.2.3 Grades*

Ground slope across the VFS shall be greater than 1% and less than 6%, measured in the direction of flow. The areas at the entrance and exits of the vegetated filter strips should be graded to provide a smooth transition for flow entering and discharging from the filter strip.

#### *8.18.2.4 Vegetation*

Filter strips should not be used on soils that cannot sustain a dense grass cover with high retardance. Grasses in filter strips must be able to withstand relatively high velocity flows at the entrances, and both wet and dry periods. For constructed or enhanced filter strips, designers should reference MARC/APWA BMP Manual Section 7.3 and plant species lists provided in Chapter 8 for a list of acceptable grasses for use in this region. In addition, non-invasive species listed in "Flora of the Great Plains" (Barkley, 1986) may be utilized. For existing vegetated areas to function as a filter strip as part of the Stormwater Management Plan, the area must contain dense grassy (nonwooded) vegetation with a minimum height of 12" providing complete coverage (no areas of open bare soil) and be able to withstand relatively high flow velocities. Turf grass is not an approved filter strip. Grass and filter strip areas shall be protected from frequent mowing in accordance with section D.3.

### 8.18.3 Value Rating

Inflow areas treated by a vegetated filter strip as described above shall be assigned a Value Rating of 5.0. A Value Rating of 9.25 for "native vegetation" shall be applied to the area of the vegetated filter strip. Note vegetated filter strips are excellent pretreatment BMPs and designers should utilize the treatment train calculation provided in Chapter 4 of the MARC/APWA BMP Manual using filter strips as the first BMP in sequence prior to swales, bioretention, detention practices, and wetlands.

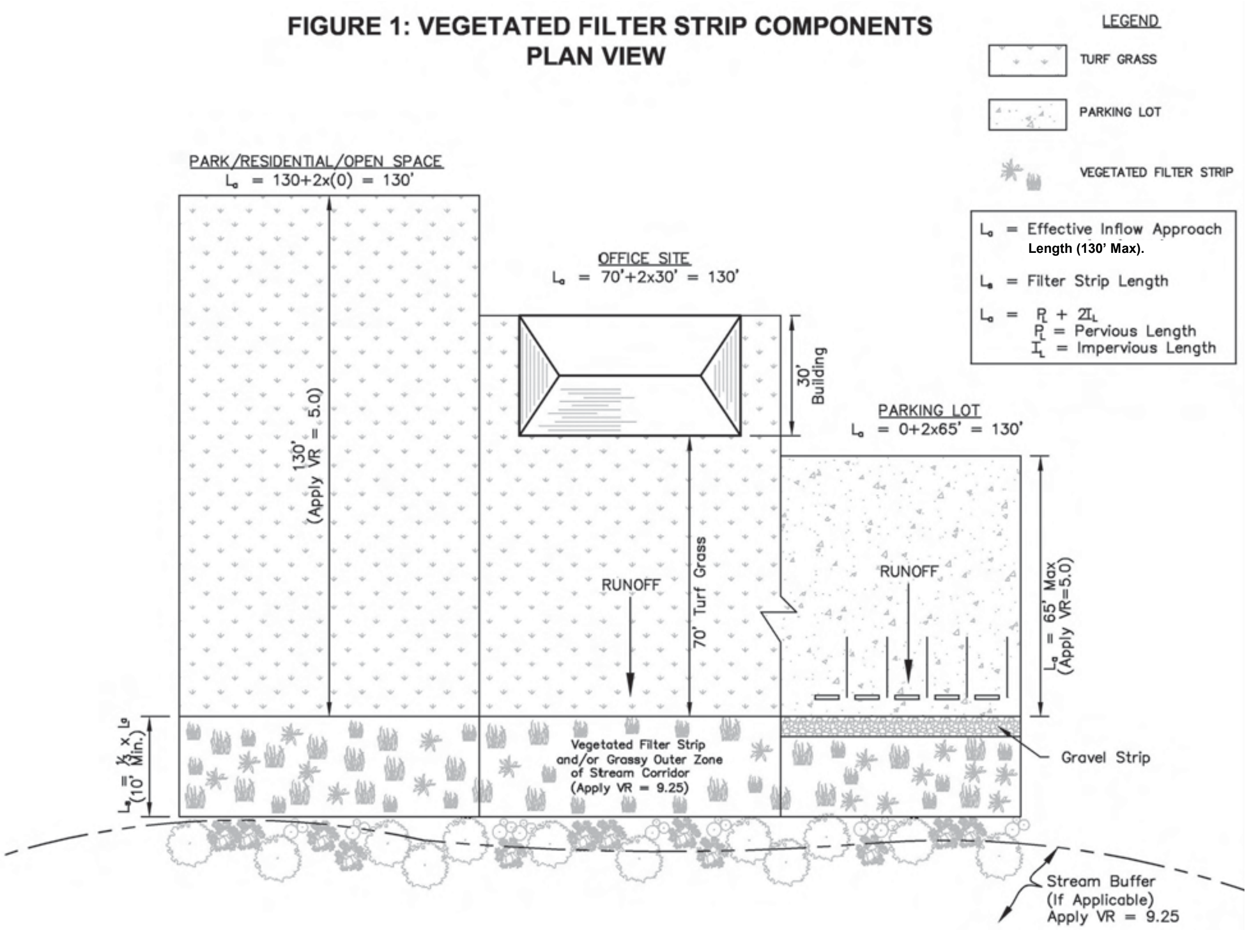



Figure 8.27 - Vegetative Filter Strip

# Section 9

## Links to Other Program Requirements

# 9.0 LINKS TO OTHER PROGRAM REQUIREMENTS

This manual complements and complies with local stormwater management programs and guidelines. The ensuing sections provide additional guidance for applying construction practices and controlling sediment and erosion to protect water quality. The following information is not a substitute for reviewing and implementing APWA Section 5100, but a complement to it.

## 9.1 PHASED CONSTRUCTION

Perform development of sites in phases. Phasing should include construction operation timelines and timelines for land disturbance and stabilization that minimize degradation of surrounding water bodies. Effective phased construction minimizes disturbed areas during the stages of a development. Consider phased construction as a BMP to include in the proper package of BMPs discussed in Section II.

In phased construction, soil is disturbed as little as possible during all construction phases to minimize erosion and prevent sediment from migrating off site. It is also imperative to limit the time of subsurface-soil exposure. For example, disturb only the part of the site applicable to immediate work. Stabilize that portion of the project before continuing to the next phase. Detail construction phasing in the erosion and sediment control plan.

More preferably on large sites, develop the tract of land in sections. For example, leave bottomland and watercourses undisturbed until uplands have been developed and stabilized. This provides a natural buffer for stormwater to slow and filter stormwater runoff from the site. After stabilizing uplands, continue development on lower lying lands. This type of phasing generates the greatest number of credits. On tracts of land over 80 acres, disturb only one-quarter of the site at a time until other sections have been stabilized.

## 9.2 SEDIMENT AND EROSION CONTROL PLANS

An erosion and sediment control plan defines and schedules control measures to minimize erosion and prevent sediment-laden stormwater from leaving the project site. Erosion and Sediment plans are required by the NPDES permitting program for construction activities. The Kansas Department of Health and Environment (KDHE), Bureau of Water, Industrial Programs Section administers the program referred to as a Stormwater Pollution Prevention Plan (SWPPP). The Missouri Department of Natural Resources (MDNR), Water Protection and Soil Conservation Division administers the program in Missouri. Each state's process is described briefly below.

In Kansas, owners or operators of any project that will disturb one or more acres must apply for authorization. Apply for the permit by completing a Notice of Intent (NOI) form at least 60 days before start of construction. A qualified professional must seal the SWPPP. The plan should include the location, installation, and maintenance of the practices foreseen to minimize erosion and prevent sediment from leaving the site.

Begin the permitting process by filing a NOI and paying a filing fee of $60 to KDHE 60 days before starting construction. Submit the SWPPP, sealed by a qualified stormwater professional. The contractor is also responsible for submitting a contractor certification form. After the project is stabilized, submit a notice of termination.

In Missouri, contact the Corps to determine if the project is in jurisdictional waters and is regulated. A project may be regulated if it involves placing materials in a lake, river, stream,- or wetland (including dry streams or wetlands). If the project is regulated, complete a 401 Certification Application Checklist. If also applying to the Corps for a 404 permit, attach the 404 permit application form (ENG Form 4345) and provide any additional information needed (and a mitigation plan when impacting a jurisdictional stream and/or wetland). Note that a 401 Certification Application is required even if the project is authorized under a nationwide permit. MDNR has a list of general conditions for certain nationwide permits. Submit the application to MDNR. The 401 Certification Application fee is $75. Upon receipt of the fee, a copy of the certification will be mailed to the appropriate office of the Corps of Engineers to inform them the certification is now in effect and final.

More information and forms required for permitting are on KDHE's web site at URL www.kdhe.state.ks.us.stormwater and MDNR's web site at URL http://www.dnr.state.mo.us/wpscd/wpcp/homewpcp.htm.

Refer to APWA 5100 for detailed guidance on preparing sediment and erosion control plans.

# Section 10

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# Appendix A

## Example Specifications

APPENDIX A

EXAMPLE CONSTRUCTION AND MATERIAL SPECI ICATIONS

# SECTION 9000 BEST MANAGEMENT PRACTICES

ANSAS CITY METROPOLITAN CHAPTER
O THE AMERICAN PUBLIC WOR S ASSOCIATION

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APPENDIX A

EXAMPLE CONSTRUCTION AND MATERIAL SPECI ICATIONS

# SECTION 9000 BEST MANAGEMENT PRACTICES

## SECTION 900 NATIVE SOIL AND VEGETATION PRESERVATION

### 900 Construction Requirements

A Selecti e clearing is removal of undesirable trees and underbrush around specimen trees and brush as designated on the drawings and/or instructed by the Engineer.

B Soil and specimen trees as shown on the drawings and/or instructed by the Engineer to save, shall be protected from damage incident to clearing, grubbing, and construction operations, by the erection of timber barriers or by such other means as the circumstances require. Such barriers must be placed and be approved by the Engineer before construction operations can proceed.

C Plant Preser ation: All plant materials on the site to be saved and/or relocated shall be marked specifically by the Engineer. No plant material may be removed from the site prior to the Engineer's inspection. All plant material to be saved/or relocated will be protected from injury to the roots and to the branches, to a distance five feet beyond the drip-line. No grading, trenching, pruning, or storage of materials may go in this area, except as approved by the Engineer.

D Trees and Plants to e Relocated: Any tree or plants moved shall be done in a timely manner so as not to delay construction progress. The Contractor shall take extra measures to protect the tree during the relocation by erecting barricades, staking, trimming, etc. as required. All trees to be relocated shall be performed by certified arborists. Tree relocation shall be performed between October 15th, and April 15th. Tree relocation shall be measured per each tree relocated, in place and accepted.



### 900 2 Construction Specifications

A Silt, snow, board, plastic fence, or other approved methods of restricting access shall be installed 5 feet outside of the drip line of trees and plant materials marked to be preserved.

B No construction activity is allowed inside these barriers.

C Avoid movement and parking of vehicles over the root zones where no grading is proposed.

D Do not store materials in restricted access areas within the drip line of trees and plant materials marked to be preserved.

E Avoid placing fill within the drip line of trees marked to be saved.

Where necessary, up to 20 percent of the area within the drip line of trees to be preserved may be disturbed when approved by the Engineer. Tree roots within the limits of disturbance shall be cleanly severed using a chainsaw or other approved mechanical method.

### 900 Inspection and Maintenance

A The Contractor and Engineer shall inspect trees for damage, stress and disease, and will bring any occurrences to the attention of the Engineer.

B The Engineer will mark trees that require repairs.

C Repairs, to include pruning, applying wound dressings, etc., shall be made by the Contractor within 7 days of occurrence.

D The Contractor shall replace trees that have been damaged beyond saving after construction is complete at no additional cost to the Owner.

E Remove the protective measures when construction is complete.

## SECTION 9002 NATIVE SOIL RESTORATION

### 9002 Materials

Prior to delivery of any materials to the site, submit to the Engineer a complete list of all materials to be used during this portion of the work. Include complete data on source, amount and quality. This submittal shall in no way be construed as permitting substitution for specific items described on the plans or in these specifications unless approved in writing by the Engineer.

### 9002 2 Topsoil

The full depth of topsoil shall be stripped from all grading areas, using a phased approach where appropriate. Topsoil up to a minimum depth of six (6) inches or the entire A horizon of the applicable soil series being disturbed as published in the Published County Soil Survey or other detailed soil survey, shall be stripped and stockpiled from all areas to be excavated or filled.

### 9002 Remo al

A All “A horizon” and topsoil shall be removed and segregated as a separate layer from the area to be disturbed. Where the Engineer determines that the topsoil is of insufficient quantity or poor quality for sustaining vegetation, other materials may be substituted with approval by the Engineer in accordance with paragraph *Substitutions and Supplements* of this section. Selected overburden materials to be substituted shall be removed as a separate layer from the area to be disturbed, and segregated.

B If topsoil is less than 6 inches thick, the operator may remove the topsoil and the unconsolidated materials immediately below the topsoil to a total depth of 6 inches and treat the mixture as topsoil.

C Timing: All material to be removed under this section shall be removed after the vegetative cover that would interfere with its salvage is cleared from the area to be disturbed, but before any drilling, blasting, excavating, or other surface disturbance takes place.

### 9002 Su stitutes and Supplements

Selected overburden materials may be substituted for, or used as a supplement to topsoil pursuant to a detailed soil survey and restoration plan that demonstrates to the Engineer that the resulting soil medium is equal to, or more suitable for sustaining vegetation than, the existing topsoil, and the resulting soil medium is the best available in the area where native soil is to be disturbed and restored. Topsoil substitutes and supplements shall consist of approximately thirty percent (30%) clay, thirty-five percent (35%) silt, thirty percent (30%) sand and five percent (5%) organic matter. Organic matter shall be Dakota Peat, biosolids, composted biomass, or other materials that are approved by the Engineer. All mixing of materials must be by a soil-blending machine and may be done either on- or off-site. The Engineer must approve the end product. After the topsoil mixture has been thoroughly blended, it shall be transported to the area of spreading and dumped at various points within the area. The material can then be moved more easily by a small crawler-type tractor suitably equipped with a blade to push the mixture onto the prepared surface. After the mixture has been spread uniformly over the surface, it must be firmed into place by light compaction with the crawler tractor. Any soft spots existing after the firming process, must be raked, floated and lightly compacted to obtain a uniform depth of placement.

### 9002 Storage

A Materials removed shall be segregated and stockpiled when it is impractical to redistribute such materials promptly on re-graded areas.

B Stockpiled materials shall meet the following requirements:

Be selectively placed on a stable site within the construction area;

2 Be protected from contaminants and unnecessary compaction that would interfere with revegetation;

Be protected from wind and water erosion through prompt establishment and maintenance of an effective, quick growing vegetative cover or through other measures provided in the approved water pollution control plan; and

Not be moved until required for redistribution unless approved by the Engineer.

C Where long-term stockpiling of materials is required, and where such stockpiling would be detrimental to the quality or quantity of those materials, the Engineer may approve the temporary distribution of the soil materials to an approved site within the construction area.

Such action will not permanently diminish the capability of the topsoil of the host site.

2 The material will be distributed in a condition more suitable for redistribution than if stockpiled.

D Redistribution

Topsoil materials removed shall be redistributed in a manner that--

a Achieves an approximately uniform, stable thickness consistent with the approved restoration plan, finished grading, and surface-water drainage systems;

Prevents excess compaction of the materials; and

c Protects the materials from wind and water erosion before and after seeding and planting.

2 Before redistribution of the material removed, the regraded land shall be scarified to reduce potential slippage of the redistributed material and to promote root penetration. Such treatment may be conducted after the material is replaced if no harm will be caused to the redistributed material and reestablished vegetation.

The Engineer may choose not to require the redistribution of topsoil or topsoil substitutes on the final embankments if it determines that--

a Placement of topsoil or topsoil substitutes on such embankments will result in greater sedimentation than would otherwise occur, or

Such embankments will be stabilized by other approved means.

### 9002 Vegetation

Vegetation shall be established on all exposed surfaces. Plantings shall be as shown in the plans and as specified.

## SECTION 900 BIORETENTION ACILITIES

### 900 Description

Bioretention facilities are small landscaped basins intended to provide water quality management by filtering stormwater runoff before release into storm drain systems. This work shall consist of installing bioretention facilities as specified in the Contract Documents, including all materials, equipment, labor and services required to perform the work.

### 900 2 Materials

A Bioretention Soil Mixture: The Bioretention Soil Mixture (BSM) is a mixture of planting soil, mulch, and sand consisting of the following:

| Item | Composition By Volume | Reference |
|---|---|---|
| Planting Soil | 30% | See below. |
| Organic Compost | 20% | See below. |
| Sand | 50% | ASTM C33 Fine Aggregate |

B Planting Soil: The USDA textural classification of the Planting Soil for the BSM shall be LOAMY SAND OR SANDY LOAM. The Planting Soil shall be the best available on site material or furnished. Additionally, the Planting Soil shall be tested and meet the following criteria or as approved by the Engineer:

| Item | Percent By Weight | Test Method |
|---|---|---|
| Sand (2.0 – 0.050 mm) | 50 – 85% | AASHTO T88 |
| Silt (0.050 – 0.002 mm) | 0 – 50% | AASHTO T88 |
| Clay (less than 0.002 mm) | 2 – 5% | AASHTO T88 |
| Organic Matter | 3 – 10% | AASHTO T194 |

The textural analysis for the Planting Soil shall be as follows:

| ASTM E Sie e Si e | Minimum Percent Passing By Weight |
|---|---|
| 2 in. | 100 |
| No. 4 | 90 |
| No. 10 | 80 |



At least 45 days prior to the start of construction of bioretention facilities, the Contractor shall submit the source and testing results of the Planting Soil for the BSM to the Engineer for approval. No time extensions will be granted should the proposed Planting Soil fail to meet the minimum requirements stated above. Once a stockpile of the Planting Soil has been sampled, no material shall be added to the stockpile.

C Organic Compost: Compost is a homogeneous and friable mixture of partially decomposed organic matter, with or without soil, resulting from composting, which is a managed process of bio-oxidation of a solid heterogeneous organic substrate including a thermophilic phase.

Compost is deemed acceptable if it meets 2 of the following requirements:

C/N ratio <= 25;

2 Oxygen uptake rate <= 150 mg $O_2$/kg volatile solids per hour; and

Compost must not contain more than 1 percent foreign matter. Foreign matter is defined as: "Any matter over a 2 mm dimension that results from human intervention and having organic or inorganic constituents such as metal, glass and synthetic polymers (e.g. plastic and rubber) that may be present in the compost but excluding mineral soils, woody material and rocks."

Foreign matter less than 1 percent by weight must not exceed 12.5 mm in any dimension.

D The Bioretention Soil Mixture BSM shall be a uniform mix, free of plant residue, stones, stumps, roots or other similar objects larger than two inches excluding mulch. No other materials or substances shall be mixed or dumped within the bioretention area that may be harmful to plant growth, or prove a hindrance to the planting or maintenance operations.

The Bioretention Soil Mixture shall be tested and meet the following criteria:

| Item | Criteria | Test Method |
|---|---|---|
| Corrected pH | 5.5 – 7.5 | ASTM D4972 |
| Magnesium | Minimum 32 ppm | * |
| Phosphorus (Phosphate - $P_2O_5$) | not to exceed 60 ppm plant available phosphorus | * |
| Potassium ($K_2O$) | Minimum 78 ppm | * |
| Soluble Salts | Not to exceed 500 ppm | * |

* Use authorized soil test procedures.

2 Should the pH fall outside of the acceptable range, it may be modified with lime (to raise) or ammonium sulfate (to lower). The lime or ammonium sulfate must be mixed uniformly into the BSM prior to use in bioretention facilities.

Should the BSM not meet the minimum requirement for magnesium, it may be modified with magnesium sulfate. Likewise, should the BSM not meet the minimum requirement for potassium, it may be modified with potash. Magnesium sulfate and potash must be mixed uniformly into the BSM prior to use in bioretention facilities.

Planting soil and/or BSM that fails to meet the minimum requirements shall be replaced at the Contractor's expense. Mixing of the corrective additives to the BSM is incidental and shall be at the Contractor's expense.

Mixing of the BSM to a homogeneous consistency shall be done to the satisfaction of the Engineer. Upon approval of all requirements and testing above, the BSM shall be stockpiled, and no material shall be added to the BSM in the stockpile or during transport to the bioretention facility.



E Other Materials

| Material | Specification |
|---|---|
| No. 57 Aggregate | ASTM D448 |
| No. 7 Aggregate | ASTM D448 |
| 4-inch HDPE Plastic Pipe Underdrain | AASHTO M252 |
| Geotextile Fabric | AASHTO M288 |
| Mulch, 2x Shredded Hardwood Bark | See below |
| Water | See below. |
| Lime | ASTM C25 |
| Ammonium Sulfate | See below. |
| Magnesium Sulfate | See below. |
| Potash | See below. |

Shredded Hardwood Mulch: Shredded hardwood mulch shall be aged a minimum of 6 months and consist of the bark and wood (50/50) from hardwood trees which has been milled and screened to a maximum 4 in. particle size and provide a uniform texture free from sawdust, clay, soil, foreign materials, and any artificially introduced chemical compounds that would be detrimental to plant or animal life.

2 Aggregate: No. 7 and No. 57 Aggregate shall be double-washed to reduce suspended solids and potential for clogging. The aggregate shall be placed as shown in the Contract Drawings.

Water: Water used in the planting, establishing, or caring for vegetation shall be free from any substance that is injurious to plant life.

Lime: Lime shall contain not less than 85 percent calcium and magnesium carbonates. Dolomitic (magnesium) lime shall contain at least 10 percent magnesium as magnesium oxide and 85 percent calcium and magnesium carbonates. Lime shall conform to the following gradation:

| Sieve Size | Minimum Percent Passing By Weight |
|---|---|
| No. 10 | 100 |
| No. 20 | 98 |
| No. 100 | 50 |

Ammonium Sulfate: Ammonium sulfate shall be a constituent of an approved horticultural product produced as a fertilizer for supplying nitrogen and as a soil acidifier.

Magnesium Sulfate: Magnesium sulfate shall be a constituent of an approved horticultural product produced as a fertilizer.

Potash: Potash (potassium oxide) shall be a constituent of an approved horticultural product produced as a fertilizer.

900 Construction



Bioretention facilities shall not be constructed until all contributing drainage areas are permanently stabilized against erosion and sedimentation as shown on the Contract Plans and to the satisfaction of the Engineer. Any discharge of sediment that affects the performance of the cell will require reconstruction of the cell to restore its defined performance. No heavy equipment shall operate within the perimeter of a bioretention facility during underdrain placement, backfilling, planting, or mulching of the facility.

A Exca ation: If the bioretention facility is to be used as a sediment basin the bioretention facility shall be excavated to the dimensions, side slopes, and *1 foot above* the bottom of the Bioretention Soil Mixture elevations shown on the Contract Plans. Any sediment from construction operations deposited in the bioretention facility shall be completely removed from the facility after all vegetation, including landscaping within the drainage area of the bioretention facility, has been established. The excavation limits shall then be final graded to the dimensions, side slopes, and *final* elevations shown on the Contract Plans. Excavators and backhoes, operating on the ground adjacent to the bioretention facility, shall be used to excavate the facility if possible. <u>low ground-contact pressure equipment</u> or, if approved by the engineer, by excavators and/or backhoes operating on the ground adjacent to the bioretention facility. Low ground-contact pressure equipment is preferred on bioretention facilities to minimize disturbance to established areas around perimeter of cell. No heavy equipment shall be used within the perimeter of the bioretention facility before, during, or after the placement of the BSM.

Excavated materials shall be removed from the bioretention facility site. Excavated materials shall be used or disposed of in conformance with the project specifications.

B Roto-tilling: After placing the underdrain and aggregate and before the BSM, the bottom of the excavation shall be roto-tilled to a minimum depth of 6 inches to alleviate any compaction of the facility bottom. Any substitute method for roto-tilling must be approved by the Engineer prior to use. Any ponded water shall be removed from the bottom of the facility and the soil shall be friable before roto-tilling. The roto-tilling shall not be done where the soil supports the aggregate bed underneath the “Underdrain for Bioretention”. (See “Underdrain for Bioretention” specifications below.)

C Underdrain for ioretention: The underdrain system, aggregate bed, and geotextile fabric shall be placed according to dimensions shown on the Contract Plans.

D O ser ation wells/cleanouts of 4-inch non-perforated HDPE pipe shall be placed vertically in the bioretention facility as shown on the Contract Plans. The wells/cleanouts shall be connected to the perforated underdrain with the appropriate manufactured connections as shown on the Contract Plans. The wells/cleanouts shall extend 6 inches above the top elevation of the bioretention facility mulch, and shall be capped with a screw cap.

E Placement of the Bioretention Soil Mixture: The Bioretention Soil Mixture (BSM) shall be placed and graded using <u>low ground-contact pressure equipment</u> or, if approved by the engineer, by excavators and/or backhoes operating on the ground adjacent to the bioretention facility. Low ground-contact pressure equipment is preferred on bioretention facilities to minimize disturbance to established areas around perimeter of cell. No heavy equipment shall be used within the perimeter of the bioretention facility before, during, or after the placement of the BSM. The BSM shall be placed in horizontal layers not to exceed 12 inches for the entire area of the bioretention facility. The BSM shall be saturated over the entire area of the bioretention facility after each lift of BSM is placed until water flows from the underdrain to lightly consolidate the BSM mixture. Water for saturation shall be applied by spraying or sprinkling in a manner to avoid separation of the BSM components. Saturation of each lift shall be performed in the presence of the Engineer. If the BSM becomes contaminated during the construction of the facility, the contaminated material shall be removed and replaced with uncontaminated material at the Contractor's expense. Final grading of the BSM shall be performed after a 24-hour settling period. Upon final grading the surface of the BSM shall be roto-tilled to a depth of 6". Final elevations shall be within 2 inches of elevations shown on the Contract Plans.

Mulching: Once grading is complete, the entire bioretention facility shall be mulched to a uniform thickness of 3 inches. Mulching shall be complete within 24 hours to reduce the potential of silt accumulation on the surface. Well aged shredded hardwood bark mulch is the only acceptable mulch. Mulching shall be done immediately after grading to reduce potential of any silt accumulation on the surface.



G Plant Installation: Trees, shrubs, and other plant materials specified for Bioretention Facilities shall be planted as specified in the Contract Plans and applicable landscaping standards with the exception that pesticides, herbicides, and fertilizer shall not be applied during planting under any circumstances. Furthermore, pesticides, fertilizer, and any other soil amendments shall not be applied to the bioretention facility during landscape construction, plant establishment, or maintenance.

900 Method of Measurement

Bioretention Facilities will be measured by the square foot and will be paid for at the Contract Unit Price.

900 Basis of Payment

The payment will be full compensation for all material, labor, equipment, tools, and incidentals necessary to satisfactorily complete the work. Biological Plantings will be paid for separately under other items of the contract.

# SECTION 900 PLANTING MANAGING NATURAL VEGETATION OR BMPs

Purposefully designed planting plans are imperative for the successful incorporation of stormwater BMP's into the developed landscape, which must meet both functional goals and aesthetic expectations of public and private clientele.

Planting design for water quality BMP's is a purposeful design process which addresses many interrelated factors including regional and site specific factors of climate / microclimate, sunlight /shade and drought / inundation. The plant selection process requires careful consideration of numerous plant characteristics and horticultural requirements. In addition, site specific factors of scale, context, aspect, soil characteristics, associated recreational facilities, aesthetics and public expectations must be considered for each individual BMP.

Sensitive transitions to adjacent plantings and well delineated edges between differing land uses or vegetation types are integral components of any design.

The designer's approach to planting plan development is similar to the development of any other garden or planting bed plan. The most successful stream corridors and other water quality BMP's will be designed and used as multifaceted facilities. Ultimately these facilities, and the plant material contained within, not only address water quality issues but are integral to the creation of habitat for birds, animals, amphibians and aquatic life, while providing recreational areas for human beings. As such, BMP designs and plant selections, especially in urban and suburban areas, requires knowledge of attributes and characteristics which are beyond the scope of this document. In order to meet these multifaceted goals, the inclusion of a registered landscape architect or botanist/plant ecologist on the design team is strongly advised.



The native plant material provided in this manual (see Table 4 in this section) includes native species commonly found within a 50-mile or so radius of the KC metro area. Developing native plant list with such a narrow focus was intentional for the purpose of ensuring 'true' natives, specific to this area (i.e., local plant genotypes), are used. It is often assumed, albeit mistakenly, that any plant native to the United States will suffice for vegetating BMP's. However, natives from Pennsylvania, for example, are technically non-native and wouldn't respond to Midwestern environmental conditions as 'true' natives. A wide variety of 'true' native plant species, found in prairies, woods, and wetlands within the 50-mile radius, can be used successfully in the BMP's described in this manual. Consequently, this narrow approach will provide a solid starting point for BMP planting design in the KC metro area. Nevertheless, it is the prerogative of the landscape designer to choose other native or ornamental plants in the creation of a specific project palette, should the need arises as a result of context, preference, and site specific characteristics of a particular BMP.

## 900 Summary

The work described herein consists of furnishing, transporting, and installing all trees, shrubs, roots, seeds, and other materials as required for the restoration and establishment of Mesic Forests, Savannas, Stream-side (riparian) Forests, Wet Prairies, Emergent Wetlands, Drainage Conveyance Swales, Ephemeral Wetlands, Mesic Prairies, and Dry Prairies and management of planting areas after final acceptance. The Contractor shall perform all planting, soil preparation, management, and such additional, extra and incidental work as may be necessary to complete the work in accordance with the specifications and plans. The Contractor shall furnish all required materials, equipment, tools, labor, and incidentals, unless otherwise provided in the specifications or plans.

A Legal Responsi ilities: The Contractor shall at all times observe and comply with all Federal and State laws, local laws, ordinances, and regulations which in any manner affect the conduct of the work, and all such orders or enactments as exist at the present and which may be enacted later, of legislative bodies or tribunals having legal jurisdiction or which may have affect over the work.

B amiliarity with o Site: The Contractor shall familiarize himself with conditions at the job site prior to the commencement of work. The Contractor shall notify the Engineer immediately if site conditions are such that inhibit progress of the work.

The Contractor shall be responsible for having all underground utilities located by servicing agency. The Contractor shall take all necessary precautions for the protection of utility facilities. The Contractor shall be responsible for any damage or destruction of utility facilities resulting from negligence or misconduct in the Contractor's manner or method of execution of the work, or caused by defective work or the use of unsatisfactory materials. Whenever any damage or destruction of a utility facility occurs as a result of work performed by the Contractor, the Utility company, Owner, and Engineer will be immediately notified.

C uality Assurance

ualifications of Workmen: Provide at least one person who shall be present at all times during execution of this portion of the work, who shall be thoroughly familiar with this type of work and the type of materials being used. Said person shall be competent at identification of plant materials to be cut, preserved, and planted during the season (summer, winter) work is to be completed. Said person shall also direct all work performed under this section.

2 Standards: All materials used during this portion of the work shall meet or exceed applicable federal, state, county and local laws and regulations. The use of any herbicide shall follow directions given on the herbicide label. In the case of a discrepancy between these specifications and the herbicide label, the label shall prevail.

D Su mittals

Materials: Prior to delivery of any materials to the site, submit to the Engineer a complete list of all materials to be used during this portion of the work. Include complete data on source, amount, and quality. This submittal shall in no way be construed as permitting substitution for specific items described on the plans or in these specifications unless approved in writing by the Engineer.



2 Licenses: Prior to any herbicide use, the Contractor shall submit to the owner a current copy of the commercial pesticide applicator's license, with certification in the Forestry or other appropriate category, for each person who will be applying herbicide at the project site. A copy of each commercial pesticide applicator's license must be maintained on site at all times during completion of the work.

Equipment: Prior to commencement of any work, submit to the Owner a written description of all mechanical equipment and its intended use during the execution of the work.

After the work is complete, submit to the Owner "as-built" plans including a listing of all species installed, and quantities installed. Mark in red ink on the original planting plan any field changes or deviations from the original plans.

E Related Sections: Section 2313 Best Management Practices

900 2 Materials

A Her icides

Herbicide to be used for woody basal applications shall be triclopyr: 3,5,6-trichloro-2-pyridinyloxyacetic acid, butoxyethyl ester, trade name Garlon 4 or equivalent as approved in writing by the Engineer.

2 Herbicide to be used for woody foliar applications shall be triclopyr: 3,5,6-trichloro-2-pyridinyloxyacetic acid, butoxyethyl ester, trade name Garlon 3 or equivalent as approved in writing by Engineer.

Herbaceous species to be removed in areas without standing water or saturated soils shall be treated with Glyphosate, N-(phosphonomethyl) glycine, trade name Roundup or equivalent as approved in writing by Engineer.

Herbaceous species to be removed in areas with standing water or saturated soils shall be treated with Glyphosate, N-(phosphonomethyl) glycine in a form approved for aquatic applications such as Rodeo or equivalent as approved in writing by Engineer.

Selective grass herbicides and other specialty herbicides may also be used in appropriate locations.

B Plant Materials

General: Plant materials shall consist of the species, quantity, and size as shown on the plans or as selected from Table 1 in these specifications and generally meet the following requirements:

a Conform to American Standard for Nursery Stock – ANS1 Z60.1.

Furnish plants and seed that are true to name and type, sound, healthy specimens representative of the species or variety with well-formed tops and healthy root systems.

c Plant material with injured bark or roots, broken branches, objectionable disfigurements, shriveled dry roots, broken pots, insect pests, diseases or other compliance deficiencies are unacceptable.

d Plant materials that experience excessive growth during storage period are unacceptable.

e Bare root plant materials that have broken dormancy are unacceptable.

f Plant materials shall be nursery grown, winter hardy stock.

g Meet or exceed specifications of Federal, State and County laws requiring inspection for plant disease and insect control and shall be labeled in accordance with U.S. Department of Agriculture Rules and Regulations under the Federal Seed Act.

h All plants shall be true be true to name and one of each bundle or lot shall be tagged with the name and size of the plants in accordance with the standards of practice of the American Association of Nurserymen. In all cases, botanical names shall take precedence over common names.



2 Deli ery Storage and Handling

a Pick up plant materials in accordance with any special handling instructions and deliver to project site in good condition.

Use all means necessary to protect plant materials before during, and after installation and to protect the installed work and materials of all other trades.

c Rootstock of the plant material shall be kept moist during transport and on-site storage.

d Provide adequate protection of root systems from drying winds and sun while plant materials are being stored. All plant materials that cannot be planted within 1 week after delivery to the project storage area shall be "heeled-in" at a site approved by the Engineer or placed in an approved cold storage site.

e Do not end or bind-tie in such a manner as to damage bark, break branches, or destroy natural shape.

f Deliver plant materials to planting sites after preparations for planting have been completed and plant immediately. If planting is delayed more than 6 hours after delivery to planting sites, set materials in shade, protect from weather and mechanical damage, and keep roots moist. Heel-in bare rootstock that cannot be planted within one day at the planting site. Soak roots in water for two hours if dried out.

Replacements: In the event of damage during storage or planting, immediately make all repairs and replacements necessary to the approval of the Engineer and at no additional cost to the Owner.

Co er Crop Seeding: All grass species shall be supplied as pure live seed. Submit to the Engineer lab germination test results. Straw or hay for erosion control shall be clean, seed-free hay or threshed straw of wheat, rye, oats, or barley.

a Prairie Co er Crop Species List

| Scientific Name | Common Name | Pounds/Acre |
|---|---|---|
| *Avena sativa (Spring)* | Oats | 30.00 |
| *Triticum* x *agropyron* (Spr./Fall) | Red-green sterile wheat | 20.00 |
| *Lolium multiflorum* (Spring) | Annual rye | 25.00 |
| *Secale cereale* (Fall) | Winter rye | 50.00 |

Wetland Co er Crop Species List

| Scientific Name | Common Name | Pounds/Acre |
|---|---|---|
| Echinochloa crusgalli | Barnyard grass | 5.00 |
| Lolium multiflorum | Annual rye | 25.00 |
| Polygonum spp. | Smartweed | 2.00 (optional) |

c Swales Co er Crop/Bioengineering

| Scientific Name | Common Name | Pounds/Acre |
|---|---|---|
| *Echinochloa crusgalli* (Spring) | Barnyard grass | 5.00 |
| *Lolium multiflorum* (Spring) | Annual rye | 50.00 |
| *Secale cereale* (Fall) | Winter rye | 50.00 |



d Tree Planting one Co er Crop

| Scientific Name | Common Name | Pounds/Acre |
|---|---|---|
| *Lolium multiflorum* | Annual rye | 30.00 |
| *Phleum pratense* | Timothy | 2.00 |

Her aceous Perennial Planting: Live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants shall be from within a 100-mile radius of the project site if at all possible and native to eastern Kansas and western Missouri. Species shall be true to their scientific name as specified. The number of plants installed will vary depending on the type of project, site conditions, and the purpose of the planting. Typically, only portions of a site are installed with live plants to improve aesthetics, add color, and improve establishment. Hence, forbs are presented in the tables below. However, planting is preferred to seeding in areas where seeding is less effective such as steep slopes, stream banks, shorelines, and inundated wetlands or ponds. Grasses and sedges would be ideal for such instances (refer to the seed mix lists). Recommended plantings are on 1- to 2- foot centers when using deep cell plug in selected areas. Larger sized plants can be placed wider apart. The plant species listed below are suggested for the different types of prairie and wetland habitats presented in Appendix A.

a Dry Prairie Species List

| Scientific Name | Common Name | lower drift Species |
|---|---|---|
| *Amorpha canescens* | Lead plant | |
| *Asclepias tuberosa* | Butterfly milkweed | X |
| *Aster azureus (A.* | Sky blue aster | X |

| Scientific Name | Common Name | lower drift Species |
|---|---|---|
| *oolentangiensis)* | | |
| *Aster ericoides* | Heath aster | X |
| *Aster laevis* | Smooth blue aster | |
| *Baptisia alba* | White wild indigo | |
| *Ceanothus americanus* | New Jersey tea | |
| *Coreopsis palmata* | Finger coreopsis | |
| *Dalea candida* | White prairie clover | X |
| *Echinacea pallida* | Pale purple coneflower | X |
| *Euphorbia corollata* | Flowering spurge | |
| *Helianthus maximilliani* | Maximillian sunflower | |
| *Heuchera richardsonii* | Alum root | |
| *Kuhnia eupatorioides* | False boneset | |
| *Liatris aspera* | Rough blazing star | |
| *Monarda fistulosa* | Wild bergamot | X |
| *Penstemon cobaea* | Cobaea beard tongue | |
| *Phlox pilosa* | Downy phlox | X |
| *Ratibida pinnata* | Yellow coneflower | |
| *Silphium laciniatum* | Compass plant | |
| *Sisyrinchium campestre* | Blue-eyed grass | |
| *Solidago nemoralis* | Old field goldenrod | X |
| *Solidago speciosa* | Showy goldenrod | X |
| *Zizia aptera* | Heart-leaved Alexander | |



Mesic Prairie Species List

| Scientific Name | Common Name | lower Drift Species |
|---|---|---|
| *Asclepias tuberosa* | Butterfly milkweed | X |
| *Aster azureus* | Sky blue aster | |
| *Aster laevis* | Smooth blue aster | |
| *Aster novae-angliae* | New England aster | |
| *Baptisia alba* | Wild false indigo | |
| *Dalea purpurea* | Purple prairie clover | |
| *Desmodium canadense* | Showy tick trefoil | |
| *Echinacea pallida* | Pale purple coneflower | X |
| *Eryngium yuccifolium* | Rattlesnake master | X |
| *Helianthus rigidus* | Rigid sunflower | |
| *Heliopsis helianthoides* | False sunflower | X |
| *Lespedeza capitata* | Bush clover | |
| *Liatris pycnostachya* | Prairie blazing star | |
| *Monarda fistulosa* | Bergamot | X |
| *Penstemon digitalis* | Fox glove beardtongue | |
| *Ratibida pinnata* | Yellow coneflower | X |

| | | |
|---|---|---|
| *Silphium laciniatum* | Compass plant | |
| *Solidago rigida* | Stiff goldenrod | X |
| *Tradescantia ohiensis* | Spiderwort | |

c Wet Prairie Species List

| Scientific Name | Common Name |
|---|---|
| *Asclepias incarnata* | Swamp milkweed |
| *Bidens cernua* | Nodding bur marigold |
| *Cicuta maculata* | Water hemlock |
| *Eupatorium maculatum* | Joe pye weed |
| *Eupatorium perfoliatum* | Boneset |
| *Helenium autumnale* | Sneezeweed |
| *Helianthus grosseserratus* | Sawtooth sunflower |
| *Lobelia siphilitica* | Great blue lobelia |
| *Lycopus americanus* | Water horehound |
| *Lythrum alatum* | Winged loosestrife |
| *Mentha arvensis* | Field mint |
| *Mimulus ringens* | Monkey flower |
| *Penthorum sedoides* | Ditch stone crop |
| *Rudbeckia laciniata* | Golden glow |
| *Silphium perfoliatum* | Cup plant |
| *Teucrium canadense* | Germander |
| *Thalictrum dasycarpum* | Meadow rue |
| *Verbena hastata* | Blue vervain |
| *Vernonia fasciculata* | Iron weed |
| *Veronicastrum virginicum* | Culvers root |



d Emergent Wetlands Species List

| Scientific Name | Common Name |
|---|---|
| Acorus calamus | Wild calamus |
| Alisma subcordatum | Water plantain |
| Asclepias incarnata | Swamp milkweed |
| Bidens cernua | Nodding bur marigold |
| Eleocharis obtusa | Blunt spikerush |
| Eupatorium perfoliatum | Boneset |
| Iris virginica | Blue flag |
| Lycopus americanus | Water horehound |
| Mentha arvensis | Field mint |
| Mimulus ringens | Monkey flower |
| Penthorum sedoides | Ditch stone crop |
| Sagittaria latifolia | Common arrowhead |
| Scirpus atrovirens | Dark green bulrush |

| Scientific Name | Common Name |
|---|---|
| Scirpus validus | Great bulrush |
| Sparganium eurycarpum | Common bur reed |

Prairie and Wetland Species Seed : All grass species shall be supplied as pure live seed. Submit to the Engineer/plant specialist lab germination test results. Seed of all species native to Eastern Kansas or Western Missouri shall be from within a 100-mile radius of the project site if at all possible. Seed mixes and species proportions for prairie, emergent wetland, and savanna plant communities will vary depending on the type of project, site conditions, plant species aggressiveness, seed variables (e.g., cost, availability, and weight), habitat type, and the purpose of the planting. A more economic seed mix for dry, mesic, wet mesic (stream buffer edge), and wet prairies would include 6 to 8 pounds of grasses and sedges and 2 pounds of wildflowers or forbs per acre (see examples below). If quicker establishment or a showier site is desired, seed mixes can be adjusted to a higher poundage such as 10 to 15 pounds of grasses and forbs or a more even proportion of 4 pounds each of grasses/sedges and wildflowers, respectively. The higher seeding rates will also help suppress weedy vegetation as the prairie becomes established. Similar proportions can be used for savanna restorations, given that the major component is prairie. For emergent wetlands, less seed per acre is necessary. Try 1 to 2 pounds of grasses/sedges per acre and 1 to 2 pounds of wildflowers per acre. A certain amount of water drawdown will be needed for seed germination. Straw or hay for erosion control shall be clean, seed-free hay or threshed straw of wheat, rye, oats, or barley.

a Dry Prairie Species List



| Scientific Name | Common Name | Ounces/ Acre | lower Drift Species |
|---|---|---|---|
| Amorpha canescens | Lead plant | 1.5 | |
| Asclepias syriaca | Common milkweed | 0.50 | |
| Asclepias tuberosa | Butterfly milkweed | 1.50 | |
| Asclepias verticillata | Whorled milkweed | 1.00 | |
| Aster azureus (A. oolentangiensis) | Sky blue aster | 1.00 | |
| Aster laevis | Smooth aster | 1.00 | |
| Avena sativa | Seed oats (cover crop) | 480.00 | |
| Baptisia bracteata | Cream false indigo | 2.00 | |
| Bouteloua curtipendula | Side oats grama | 56.00 | |
| Carex gravida | Grave sedge | 4.00 | |
| Carex meadii | Mead’s sedge | 4.00 | |
| Coreopsis palmata | Finger coreopsis | 1.00 | |
| Desmodium canadense | Showy tick trefoil | 1.00 | |
| Elymus canadensis | Canada wild rye | 16.00 | |
| Helianthus maximilliani | Maximillian sunflower | 1.00 | X |
| Heliopsis helianthoides | False sunflower | 1.00 | X |
| Heuchera richardsonii | Alum root | 0.50 | |
| Lespedeza capitata | Roundhead Bushclover | 1.00 | |
| Liatris aspera | Rough blazing star | 1.00 | |
| Monarda fistulosa | Wild bergamot | 2.00 | X |

| Scientific Name | Common Name | Ounces/ Acre | lower Drift Species |
|---|---|---|---|
| Oenothera biennis | Common evening primrose | 1.00 | X |
| Ratibida pinnata | Yellow coneflower | 4.00 | X |
| *Rudbeckia hirta* | Black-eyed Susan | 4.00 | X |
| *Schizachyrium scoparium* | Little bluestem grass | 56.00 | |
| *Silphium laciniatum* | Compass plant | 1.00 | |
| *Solidago rigida* | Stiff goldenrod | 2.00 | |
| *Sorghastrum nutans* | Indian grass | 8.00 | |
| *Sporobolus heterolepis* | Prairie dropseed | 16.00 | |
| *Tradescantia bracteata* | Prairie spiderwort | 1.00 | |
| *Verbena stricta* | Hoary vervain | 2.00 | X |
| * 10 lbs. of grasses and sedges; 2 lbs. of forbs* | | | |

Mesic Prairie Species List



| Scientific Name | Common Name | Ounces/ Acre | **Flower Drift Species** |
|---|---|---|---|
| *Amorpha canescens* | Lead plant | 1.0 | |
| *Andropogon gerardii* | Big bluestem grass | 48.00 | |
| *Asclepias syriaca* | Common milkweed | 0.50 | |
| *Aster azureus* | Sky blue aster | 1.00 | |
| *Aster praealtus* | Willow aster | 1.00 | |
| *Avena sativa* | Seed Oats (cover crop) | 480.00 | |
| *Baptisia australis* | Blue wild indigo | 1.00 | |
| *Bouteloua curtipendula* | Side oats grama | 8.00 | |
| *Carex meadii* | Mead's sedge | 4.00 | |
| *Carex molesta* | Pest sedge | 4.00 | |
| *Coreposis palmata* | Finger coreopsis | 1.00 | |
| *Dalea purpurea* | Purple prairie clover | 1.00 | |
| *Desmodium canadense* | Showy tick trefoil | 1.50 | X |
| *Echinacea pallida* | Pale purple coneflower | 2.00 | |
| *Elymus canadensis* | Canada wild rye | 8.00 | |
| *Eryngium yuccifolium* | Rattlesnake master | 1.50 | |
| *Heliopsis helianthoides* | False sunflower | 1.00 | X |
| *Lespedeza capitata* | Bush clover | 1.50 | |
| *Liatris pycnostachya* | Prairie blazing star | 1.00 | |
| *Monarda fistulosa* | Wild bergamot | 2.00 | X |
| *Oenothera biennis* | Common evening primrose | 1.00 | X |
| *Panicum virgatum* | Switch grass | 8.00 | X |
| *Penstemon digitalis* | Smooth penstemon | 0.50 | |
| *Ratibida pinnata* | Yellow coneflower | 3.00 | X |

| Scientific Name | Common Name | Ounces/ Acre | **Flower Drift Species** |
|---|---|---|---|
| *Rudbeckia hirta* | Black-eyed susan | 3.50 | X |
| *Schizachyrium scoparium* | Little bluestem grass | 32.00 | |
| *Silphium laciniatum* | Compass plant | 2.00 | |
| *Solidago rigida* | Stiff goldenrod | 1.00 | X |
| *Solidago speciosa* | Showy goldenrod | 1.00 | |
| *Sorghastrum nutans* | Indian grass | 24.00 | |
| *Tradescantia ohiensis* | Ohio spiderwort | 1.00 | |
| *Verbena stricta* | Hoary vervain | 1.00 | |
| *Zizia aptera* | Heart-leaved Alexander | 1.00 | |
| * 8 lbs. of grasses and sedges; 2 lbs. of forbs* | | | |

c Wet Prairie WP and Stream Buffer Edge Wet Mesic Prairie BE Species List

| Scientific Name | Common Name | Seeding Rate y one Ounces/Acre | |
|---|---|---|---|
| | | WP | BE |
| *Andropogon gerardii* | Big bluestem | 32.00 | 48.00 |
| *Anemone canadensis* | Meadow anemone | 2.00 | 3.00 |
| *Asclepias incarnata* | Swamp milkweed | 4.00 | 4.00 |
| *Aster novae-angliae* | New England aster | 1.00 | 2.00 |
| *Avena sativa* | Oats (cover crop) | 480.00 | 480.00 |
| *Bidens cernuus* | Nodding beggar-ticks | 2.00 | 3.00 |
| *Calamagrostis canadensis* | Blue joint grass | 4.00 | 4.00 |
| *Carex annectans* | Yellow-fruited sedge | 4.00 | -- |
| *Carex cristatella* | Crested sedge | 4.00 | -- |
| *Carex frankii* | Frank's sedge | 2.00 | 3.00 |
| *Carex vulpinoidea* | Fox sedge | 32.00 | 32.00 |
| *Cicuta maculata* | Water hemlock | 1.00 | -- |
| *Echinochloa crusgali* | Barnyard grass (cover crop) | 6.00 | 6.00 |
| *Eleocharis obtusa* | Blunt spikerush | 3.00 | -- |
| *Elymus virginicus* | Virginia Wild rye | 10.00 | 24.00 |
| *Eupatorium perfoliatum* | Boneset | 2.00 | 2.00 |
| *Glyceria striata* | Fowl manna grass | 1.00 | 2.00 |
| *Helenium autumnale* | Sneezeweed | 1.00 | -- |
| *Helianthus grosseserratus* | Sawtooth Sunflower | 3.00 | 4.00 |
| *Juncus torreyi* | Torrey's rush | 1.00 | 2.00 |
| *Leersia oryzoides* | Rice cutgrass | 2.00 | |
| *Lobelia siphilitica* | Great blue lobelia | 1.00 | 1.00 |
| *Lycopus americanus* | Common water horehound | 1.00 | 1.00 |
| *Lythrum alatum* | Winged loosestrife | 1.00 | 1.00 |

| | | Seeding Rate y one Ounces/Acre | |
|---|---|---|---|
| Scientific Name | Common Name | WP | BE |
| *Mimulus ringens* | Monkey flower | 1.00 | 1.00 |
| *Panicum virgatum* | Switch grass | 4.00 | 4.00 |
| *Rudbeckia laciniata* | Wild golden glow | 1.00 | 2.00 |
| *Scirpus atrovirens* | Dark green rush | 0.50 | 0.50 |
| *Scirpus validus* | Softstem bulrush | 0.50 | 0.50 |
| *Silphium perfoliatum* | Cup plant | 2.00 | 2.00 |
| *Solidago gigantea* | Tall goldenrod | 2.00 | -- |
| *Spartina pectinata* | Prairie cord grass | 28.00 | 8.00 |
| *Teucrium canadense* | Germander, Wood sage | 1.00 | 2.00 |
| *Thalictrum dasycarpum* | Purple meadow rue | 2.00 | -- |
| *Verbena hastata* | Blue vervain | 2.00 | 4.00 |
| *Veronicastrum virginiana* | Culver's root | 2.00 | -- |
| * 8 lbs. of graminoids (i.e., grasses, sedges, and bulrushes) and 2 lbs. of forbs* | | | |



d Emergent Wetland Species List

| Scientific Name | Common Name | Ounces/Acre |
|---|---|---|
| *Acorus calamus* | Wild calamus | 1.00 |
| *Alisma subcordatum* | Water plantain | 8.00 |
| *Bidens cernua* | Nodding beggar-ticks | 4.00 |
| *Calamagrostis canadensis* | Blue joint grass | 5.00 |
| *Carex hystricina* | Bottlebrush sedge | 6.00 |
| *Carex vulpinoidea* | Fox sedge | 6.00 |
| *Echinochloa crusgalli* | Barnyard grass (cover crop) | 5.00 |
| *Juncus torreyi* | Torrey's rush | 1.00 |
| *Leersia oryzoides* | Rice cutgrass | 6.00 |
| *Lobelia siphilitica* | Great blue lobelia | 1.00 |
| *Lolium multiflorum* | Annual rye (cover crop) | 25.00 |
| *Lycopus americanus* | Common water horehound | 1.50 |
| *Mimulus ringens* | Monkey flower | 1.50 |
| *Nelumbo odorata* | American lotus | 2.00 |
| *Polygonum pensylvanicum* | Lady's thumb | 8.00 |
| *Sagittaria latifolia* | Arrowhead | 4.00 |
| *Scirpus atrovirens* | Dark green rush | 2.00 |
| *Scirpus fluviatilis* | River bulrush | 1.00 |
| *Scirpus validus* | Softstem bulrush | 1.00 |
| *Sparganium americanum* | Common bur reed | 4.00 |
| *Verbena hastata* | Blue vervain | 2.00 |
| * 2 lbs. of graminoids (i.e., grasses, sedges, and bulrushes) and 2 lbs. of forbs* | | |

e Sa anna Species List

| Scientific Name | Common Name | **Ounces/Acre** |
|---|---|---|
| *Agastache nepetoides* | Yellow giant hyssop | 1.00 |
| *Andropogon gerardii* | Big bluestem | 2.00 |
| *Anemone cylindrica* | Tall thimbleweed | 0.50 |
| *Aquilegia canadensis* | Wild columbine | 0.50 |
| *Asclepias purpurascens* | Purple milkweed | 0.50 |
| *Aster laevis* | Smooth blue aster | 0.50 |
| *Bromus pubescens* | Woodland brome | 8.00 |
| *Carex blanda* | Woodland sedge | 1.00 |
| *Carex rosea* | Woodland sedge | 1.00 |
| *Carex sparganioides* | Woodland sedge | 1.00 |
| *Desmodium canadense* | Showy tick trefoil | 1.00 |
| *Elymus canadensis* | Canada wild rye | 4.00 |
| *Eupatorium purpureum* | Purple joy-pye weed | 0.25 |
| *Geranium maculatum* | Wild geranium | 0.25 |
| *Helianthus divaricatus* | Woodland sunflower | 0.50 |
| *Hystrix patula (Elymus hystrix)* | Bottlebrush grass | 8.00 |
| *Liatris aspera* | Rough blazing star | 1.00 |
| *Monarda fistulosa* | Wild bergamot | 1.00 |
| *Panicum virgatum* | Switch grass | 5.00 |
| *Penstemon digitalis* | Foxglove beard tongue | 0.50 |
| *Ratibida pinnata* | Yellow coneflower | 2.00 |
| *Rudbeckia hirta* | Black-eyed susan | 2.00 |
| *Schizachyrium scoparium* | Little bluestem grass | 2.00 |
| *Silphium integrifolium* | Rosinweed | 1.50 |
| *Smilacina racemosa* | False Solomon's seal | 1.00 |



| Scientific Name | Common Name | Plants/Acres |
|---|---|---|
| *Solidago ulmifolia* | Elmleaf goldenrod | 1.00 |
| *Tradescantia ohiensis* | Ohio spiderwort | 1.00 |
| *Verbena stricta* | Hoary vervain | 0.50 |
| * 2 lbs. of grasses and sedges; 1 lb. of forbs* | | |

Tree and Shru  Species: Seedling protection tubes shall be 4" diameter, 24" tall, photodegradable plastic, with a 2-year life span, such as Pro/Gro tubes manufactured by Protex, or equivalent with written approval by the Engineer. Trees shall be from within a 150-mile radius of the project site. All trees shall be 1 to 2" caliber bare root nursery grown stock unless approved in writing by the Engineer.

a Sa anna Species List

| Scientific Name | Common Name | Plants/Acres |
|---|---|---|

| | | |
|---|---|---|
| *Corylus americana* | Hazelnut | 16 |
| *Quercus alba* | White oak | 25 |
| *Quercus macrocarpa* | Bur oak | 25 |
| *Quercus rubra* | Red oak | 25 |

900 Selecti e Woody Brush Remo al

A Description: This section includes the selective cutting and disposal of woody brush including trees and shrubs.

B Method

The Contractor will cut all woody species designated for removal in up to approximately 12.5 acres of woods with hand tools including, but not necessarily limited to, gas powered chain saws, gas powered clearing saws, bow saws, and loppers.

2 All stumps shall be cut flat with no sharp points, and to within two inches of surrounding grade.

Removal of undesirable woody species shall preferentially occur when the ground is frozen.

Stumps shall be left in the ground and not removed. All stumps shall be treated with an approved herbicide mixed with a marking dye.

Girdling may also be used in combination with cutting and stump herbicide treatment if approved in writing by the owner. Trees to be girdled shall have a one inch deep notch cut completely around the trunk approximately 36" above surrounding grade. A basal application of an approved herbicide shall also be used following label directions.



Stack cut brush in piles not to exceed eight (8) feet in height by twelve (12) foot in diameter. Piles shall be spaced as necessary to minimize dragging of cut material over long distances. Piles shall be located in open areas without canopy branches of preserved trees overhanging the piles. Piles shall be burned on site. Ensure no debris (rubble, plastic, etc.) other than the cut brush is placed in the burn piles.

A supply of chemical absorbent shall be maintained at the project site. Any chemical spills shall be properly cleaned up and reported to the owner within 24 hours.

The Contractor shall maintain copies at the project site of all current pesticide applicator's licenses, herbicide labels, and MSDS's (Material Safety Data Sheets) for all chemicals utilized during completion of the work.

9 Species designated for removal shall be determined for a specific site and may include some or all of the following invasive plant species or noxious weeds:

| Common Name | Scientific Name | Disposition |
|---|---|---|
| Saltcedar | *Tamarix* spp. | Remove all |
| Boxelder | *Acer negundo* | Remove all |
| Russian olive | *Elaeagnus angustifolia* | Remove all |
| Autumn olive | *Elaeagnus umbellata* | Remove all |
| Common buckthorn | *Rhamnus cathartica* | Remove all |
| Multiflora rose | *Rosa multiflora* | Remove all |
| Morrow's honeysuckle | *Lonicera morrowii* | Remove all |
| Tartarian honeysuckle | *Lonicera tatarica* | Remove all |

| Common Name | Scientific Name | Disposition |
|---|---|---|
| Amur honeysuckle | *Lonicera maackii* | Remove all |
| Japanese honeysuckle | *Lonicera japonica* | Remove all |
| Showy fly honeysuckle | *Lonicera* x *bella* | Remove all |
| Prickly ash | *Zanthoxylum americanum* | Reduce by 50% |
| Sericea lespedeza | *Lespedeza cuneata* | Remove all |
| Red elm | *Ulmus rubra* | Reduce by 50% |
| Green ash | *Fraxinus pennsylvanica subintegerrima* | Reduce by 50% |
| Gray dogwood | *Cornus racemosa* | Reduce by 50% |
| Rough-leaved dogwood | *Cornus drummondii* | Reduce by 50% |
| Winter creeper | *Euonymus fortunei* | Remove all |

C Clean-Up Remo al and Repair

Clean up: The work area shall be kept free of debris by the Contractor. At no time shall empty herbicide containers, trash, or other material be allowed to accumulate at the project site. All tools shall be kept in appropriate carrying cases, toolboxes, etc. Parking areas, roads, sidewalks, paths and paved areas shall be kept free of mud and dirt.



2 Remo al: After work has been completed remove tools, empty containers, and all other debris generated by the Contractor.

Repair: Repair any damages caused by the Contractor during completion of the work described in this Section. Said damages may include, but are not limited to, tire ruts in the ground, damage to lawn areas, damage to trails, etc. In the event any vegetation designated to be preserved is damaged, notify the owner within 24 hours. The Contractor shall be liable for remedying said damages to plant materials.

D Inspection

After completion of selective woody brush removal, the Contractor shall schedule with the Owner a provisional acceptance inspection of the work.

2 After provisional acceptance of selective woody brush removal, the Contractor shall conduct a year-end inspection of work areas. Within five business days of the inspection, the Contractor shall notify the owner in writing of the results of the inspection, and noting any stumps that have re-sprouted.

E Acceptances and Guarantee

Pro isional Acceptance: The work shall be provisionally accepted by the Owner after initial selective woody brush removal is completed per the given plans and specifications, and the Contractor has completed all clean up, removal, and repair as described in this section. Selective woody brush removal shall be considered 75% complete at the time of provisional acceptance.

2 inal Acceptance: Selective woody brush removal shall be considered 100% complete after the Contractor has complied with all provisions of the Guarantee described in this section.

Guarantee: The Contractor guarantees not more than 10% of the cut stumps shall be re-sprouting at any time. The Contractor shall guarantee the work until one full year after brushing.

900 Her aceous Species Remo al

A Description: This section includes the eradication of herbaceous species, including grasses and forbs. This work will occur in the areas to be restored to prairies, areas to be restored to wetlands and areas to receive native landscaping treatments.

B Method

The Contractor will treat all vegetation within targeted areas with an approved herbicide, applied by a certified application, in accordance with applicable laws. Herbicide application instructions given on the label shall be followed at all times.

2 Targeted areas may be shown on plans or located in the field by the Engineer.

Care shall be taken not to affect vegetation outside of target areas.

A supply of chemical absorbent shall be maintained at the project site. Any chemical spills shall be properly cleaned up and reported to the Engineer within 24 hours.

The Contractor shall maintain copies at the project site of all current pesticide applicator's licenses, herbicide labels, and MSDS's (Material Safety Data Sheets) for all chemicals utilized during completion of the work.

Herbicide may be applied using a backpack sprayer, a hand-held wick applicator, or a vehicle mounted high-pressure spray unit, as specified by the chemical label, in accordance with applicable laws.

Species designated for removal shall be determined for a specific site and may include some or all of the following invasive plant species and noxious weeds:



| Common Name | Scientific Name | Disposition |
|---|---|---|
| Crown vetch | *Coronilla varia* | Remove all |
| Purple loosestrife | *Lythrum salicaria* | Remove all |
| Cut-leaf teasel | *Dipsacus laciniatus* | Remove all |
| Fuller's teasel | *Dipsacus fullonum* | Remove all |
| Garlic mustard | *Allilaria petiolata* | Remove all |
| Musk thistle | *Carduus nutans* | Remove all |
| Canada thistle | *Cirsium arvense* | Remove all |
| Bull thistle | *Cirsium vulgare* | Remove all |
| Scotch thistle | *Onopordum acanthium* | Remove all |
| Yellow and white sweet clover | *Melilotus officinalis*, *M. alba* | Remove all |
| Kudzu | *Pueraria lobata* | Remove all |
| Field bindweed | *Convolvulus arvensis* | Remove all |
| Russian knapweed | *Centaurea picris* | Remove all |
| Pignut | *Hoffmannseggia densiflora* | Remove all |
| Burragweed | *Franseria tomentosa; F. discolor* | Remove all |
| Leafy spurge | *Euphorbia esula* | Remove all |
| Hoary cress | *Lepidium draba* | Remove all |
| Quackgrass | *Agropyron repens* | Remove all |
| Reed canary grass | *Phalaris arundinacea* | Remove all |
| Johnson grass | *Sorghum halepense* | Remove all |
| Marijuana | *Cannabis sativa* | Remove all |
| Caucasian bluestem | *Bothriochloa bladhi* | Remove all |
| Silver beardgrass | *Bothriochloa laguroides* | Remove all |
| Smooth brome | *Bromus inermis* | Remove all |

| Common Name | Scientific Name | Disposition |
|---|---|---|
| Tall fescue | *Festuca arundinacea* | Remove all |

Other non-native species, not listed here, may also preclude the establishment of native vegetation, and should be removed if found on-site.

C Clean-Up Remo al and Repair

Clean-Up: The work area shall be kept free of debris by the Contractor. At no time shall empty herbicide containers, trash, or other material be allowed to accumulate at the project site. All tools shall be kept in appropriate carrying cases, toolboxes, etc. Parking areas, roads, sidewalks, paths and paved areas shall be kept free of mud and dirt.

2 Remo al: After work has been completed remove tools, empty containers, and all other debris generated by the Contractor, in accordance with the chemical label and applicable laws.

Repair: Repair any damages caused by the Contractor during completion of the work described in this Section. Said damages may include, but are not limited to, tire ruts in the ground, damage to lawn areas, damage to trails, etc. In the event any vegetation outside of targeted areas is damaged, notify the Owner within 24 hours. The Contractor shall be liable for remedying said damages to plant materials.

D Inspection

After completion of herbaceous species removal, the Contractor shall schedule with the Owner a provisional acceptance inspection of the work.

2 After provisional acceptance of herbaceous species removal, the Contractor shall conduct monthly inspections of work areas until the end of the current growing season. Within five business days of the inspection, the Contractor shall notify the Engineer by telephone of the results of the inspection.



E Acceptance and Guarantee

Pro isional Acceptance: The work shall be provisionally accepted by the Owner after initial herbaceous species removal is completed per the given plans and specifications, and the Contractor has completed all clean up, removal, and repair as described in 3.2 of this section. Herbaceous species removal shall be considered 90% complete at the time of provisional acceptance.

2 inal Acceptance: Herbaceous species removal shall be considered 100% complete after the Contractor has complied with all provisions of the Guarantee described in 3.4C of this section.

Guarantee: The Contractor guarantees not more than 10% vegetative cover within the treated area at any time. The Contractor shall guarantee the work until provisional acceptance of Seeding, Herbaceous perennial planting, and/or tree and shrub planting in the targeted area.

900 Soil Preparation

A Description: This section includes preparation of soil prior to seeding and/or planting for areas to be restored to prairies, wetlands and native landscaping in areas currently dominated by agricultural or weedy vegetation, old fields, etc. All herbaceous species removal will be done prior to soil preparation.

B Method

Prior to seeding and planting, rotovate soils to produce a fine seedbed.

2 Soils shall not have a measured compaction greater five pounds per square inch, based on Lang or Cone penetrometer measurements, at the time of seeding or planting unless otherwise stated on the plans or in the specifications. If ten percent or more of penetrometer readings are greater than five

pounds per square inch, disc, rotovate, and/or chisel plow said areas as necessary to reduce compaction.

Re-check soil compaction as described above after tillage. Repeat treatment until ninety percent or more of penetrometer readings are less than five pounds per square inch.

Remove all foreign matter larger than one inch in any dimension from the areas to be seeded and/or planted.

C Clean-Up Remo al and Repair

Clean-Up: After soil preparation is complete, clean up any remaining materials, debris, trash, etc. Avoid driving over the area to minimize additional compaction.

2 Repair: Repair any damages caused by the Contractor during completion of the work described in this Section.

D Inspection: After completion of soil preparation, the Contractor shall schedule with the Owner a final acceptance inspection of soil preparation.

E Acceptance and Guarantee:

inal Acceptance: this portion of the work shall be considered 100% complete after the Contractor has completed soil preparation, and completed all required clean up as described in this section.

900 Co er Crop Seeding

A Description: This section includes installation of cover crop seed in any area of disturbed soil that may or may not be final planted to native, plantings and species.

B Method

Seeds shall have proper stratification and/or scarification to break seed dormancy for spring planting.

2 Seeding shall be preferentially conducted as a late fall dormant seeding (after December 1) or in early spring (as soon as the soil is free of frost and in a workable condition but no later than July 15).

All seed shall be preferentially installed with a rangeland type grain drill or no-till planter, such as by Truax, or equivalent as approved in writing by the Owner.

If soil is too wet to install seed as described above, a mechanical broadcast seeder, such as by Cyclone, shall be used. Hand broadcasting of seed may also be employed. Within 24 hours, or as soon as site conditions permit, broadcast seeded areas shall be rolled or dragged perpendicular to the slope.

Within seven days of seeding, crimp 2,000 pounds per acre of straw or hay for erosion control onto slopes greater than one foot horizontal to five foot vertical (1:5).

If area to be seeded was treated with herbicide, seeding shall occur no less than 14 days after herbicide application.

C Clean-Up Remo al and Repair

Clean-Up: The work area shall be kept free of debris by the Contractor. After seed installation is complete, clean up any remaining materials, debris, trash, etc. Avoid driving over seeded areas to minimize disturbance

2 Removal: After work has been completed remove any tools, equipment, empty containers, and all other debris generated by the Contractor.

Repair: Repair any damages caused by the Contractor during completion of the work described in this section.

D Inspection: After completion of seeding, the Contractor shall schedule with Owner a provisional acceptance inspection of the work.

E Acceptance and Guarantee

Pro isional Acceptance: The work shall be considered 90% complete after all seed has been installed and the Contractor has completed all required clean up, removal, and repair as described in this section.

2 inal Acceptance: The work shall be considered 100% complete after the Contractor has met or exceeded the performance standards given in this section, and completed all required clean up, removal, and repair as described in this section.

The Contractor shall guarantee seeded areas will meet or exceed the following performance criteria one full growing season after provisional acceptance: 70% plant cover.

900 Her aceous Perennial Planting

A Description: This section includes installation of live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants.



B Method

Planting of all live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants shall be completed after May 15 but no later than July 15.

2 All live herbaceous plants shall be potted, two year old nursery grown stock unless approved in writing by the Owner.

All live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants shall be approved by the Owner prior to installation.

Provide healthy, vigorous live herbaceous perennial plants; provide freshly dug tubers, bulbs, and dormant rootstocks of herbaceous perennial plants. Do not use materials that have been in cold storage for longer than 45 days.

Deliver live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants to project site after preparations for planting have been completed.

Live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks shall be packed in such a manner as to insure adequate protection against wind damage, desiccation, and other physical damage while in transit.

If planting is delayed more than four hours after delivery, keep plants in refrigerated container or set plants in shade protected from weather and mechanical damage, and keep moist and cool.

Live herbaceous emergent perennial plants, tubers, bulbs, and dormant rootstocks shall be installed in 0-6” depth of water.

9 Emergent live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants shall be clustered into groups of 25-50 individuals of the same species.

0 Dry prairie, mesic prairie, wet prairie, and wetlands live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants shall be clustered into groups of 75-125 individuals of randomly mixed species from the species lists given in this section.

All live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants shall be adequately healed in to prevent desiccation.

2 All groupings of live herbaceous emergent perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants shall be protected from wildlife herbivory, if necessary, on all four sides by 36-48" high fencing attached to wooden stakes. The Contractor shall submit shop drawings, including a materials list, to the Owner for approval prior to installation. Said fencing shall be removed by the Contractor one full growing season after installation or as otherwise directed by the Owner.

If planting into an area treated with herbicide, plant materials shall be installed not less than 14 days after herbicide treatment.

C Clean-Up Remo al and Repair

Clean-Up: The work area shall be kept free of debris by the Contractor. After the work is complete, clean up any remaining materials, plant containers, debris, trash, etc. Avoid driving or walking over planted areas to minimize disturbance.

2 Remo al: After work has been completed remove any tools, equipment, empty containers, and all other debris generated by the Contractor.

Repair: Repair any damages caused by the Contractor during completion of the work described in this section.

D Inspection: After completion of planting and fencing, the Contractor shall schedule with the Owner a provisional acceptance inspection of the work.



E Acceptance and Guarantee

Pro isional Acceptance: the work shall be considered 90% complete after initial planting and construction of fencing, and after the Contractor has completed all required clean up, removal, and repair as described in this section.

2 inal Acceptance: The work shall be considered 100% complete after the Contractor has met or exceeded the performance standards given in this section, completed all required clean up, removal, and repair as described in this section, and removed fencing as described in this section.

The Contractor shall guarantee planted areas will meet or exceed the following performance criteria one full growing season after provisional acceptance: 10% survivorship of all planted species

900 Seeding

A Description: This section includes installation of seed.

B Method

Seeds shall have proper stratification and/or scarification to break seed dormancy for spring planting.

2 All legumes shall be inoculated with proper rhizobia at the appropriate time prior to planting.

Seeding shall be preferentially conducted as a late fall dormant seeding (after November 1) or in early spring (as soon as the soil is free of frost and in a workable condition but no later than July 15).

All seed on drivable slopes shall be preferentially installed with a rangeland type grain drill or no-till planter, such as by Truax, or equivalent as approved in writing by the Owner.

If soil is too wet to install seed as described in 3.1D. above, a mechanical broadcast seeder, such as by Cyclone, shall be used. Hand broadcasting of seed may also be employed. Within 24 hours, or as soon as site conditions permit, broadcast seeded areas shall be rolled or dragged perpendicular to the slope. Hydro seeding and mulching onto a lightly disked soil surface is also an acceptable method.

Contractor shall provide specifications on the nature of the equipment, mulching system, and tackifier that would be used if hydro seeding/mulching is the chosen procedure.

Within seven days of seeding, crimp 2,000 pounds per acre of clean weed free straw or hay for erosion control onto slopes greater than one foot horizontal to five foot vertical (1:5).

If area to be seeded was treated with herbicide, seeding shall occur no less than 14 days after herbicide application.

C Clean-Up Remo al and Repair

Clean-Up: The work area shall be kept free of debris by the Contractor. After seed installation is complete, clean up any remaining materials, debris, trash, etc. Avoid driving over seeded areas to minimize disturbance.

2 Remo al: After work has been completed remove any tools, equipment, empty containers, and all other debris generated by the Contractor.

Repair: Repair any damages caused by the Contractor during completion of the work described in this section.

D Inspection: After completion of seeding, the Contractor shall schedule with Owner a provisional acceptance inspection of the work.



E Acceptance and Guarantee

Pro isional Acceptance: The work shall be considered 90% complete after all seed has been installed and the Contractor has completed all required clean up, removal, and repair as described in this section.

2 inal Acceptance: The work shall be considered 100% complete after the Contractor has met or exceeded the performance standards given in this section, and completed all required clean up, removal, and repair as described in this section.

The Contractor shall guarantee seeded areas will meet or exceed the following performance criteria one full growing season after provisional acceptance: 70% plant cover, seedlings of three planted grass/sedge species found, and seedlings of three planted forb species found.

The Contractor shall guarantee seeded areas will meet or exceed the following performance criteria two full growing seasons after provisional acceptance: 80% plant cover, 5% cover by planted native grass/sedge species, 10% cover by planted forb species, and 20% of planted species are found.

900 9 Tree and Shru Planting

A Description: This section includes planting of trees and shrubs.

B Method

Planting of trees shall be completed as soon as the soil is free of frost and in a workable condition but no later than July 15.

2 All trees shall be approved by the Engineer prior to installation.

Provide healthy, vigorous, freshly dug plant materials. Do not use materials that have been dug more than 30 days in advance.

Deliver trees to project site after preparations for planting have been completed.

Trees shall be packed in such a manner as to insure adequate protection against wind damage, desiccation, and other physical damage while in transit.

If planting is delayed more than four hours after delivery, keep plants in refrigerated container or set plants in shade protected from weather and mechanical damage, and keep moist and cool.

Trees shall be randomly planted from the species lists given in this section.

A seedling protection tube shall be installed around every tree and shrub within seven days of planting. Seedling protection tubes shall be secured to the ground with a 3/8"x36" bamboo stake and plastic cable tie. Seedling protection tubes shall not be removed by the Contractor unless directed by the Engineer.

9 If planting into an area treated with herbicide, plant materials shall be installed not less than 14 days after herbicide treatment.

C Clean-Up Remo al and Repair

Clean-Up: The work area shall be kept free of debris by the Contractor. After the work is complete, clean up any remaining materials, plant containers, debris, trash, etc. Avoid driving or walking over planted areas to minimize disturbance.

2 Remo al: After work has been completed remove any tools, equipment, empty containers, and all other debris generated by the Contractor.

Repair: Repair any damages caused by the Contractor during completion of the work described in this Section.

D Inspection: After completion of the work, the Contractor shall schedule with the Owner a provisional acceptance inspection of the work.

E Acceptance and Guarantee



Pro isional Acceptance: The work shall be considered 90% complete after initial planting and installation of seedling protection tubes, and after the Contractor has completed all required clean up, removal, and repair as described in this section.

2 inal Acceptance: The work shall be considered 100% complete after the Contractor has met or exceeded the performance standards given in this section, and has completed all required clean up, removal, and repair as described in this section.

The Contractor shall guarantee planted areas will meet or exceed the following performance criteria one full growing season after provisional acceptance: 50% survivorship of all planted species.

900 0 Management

A Description: Seeding, herbaceous perennial planting, tree and shrub planting, woody brush removal.

B Her icide Application

The Contractor will treat all undesirable species with an approved herbicide. Herbicide application instructions given on the label shall be followed at all times.

2 Undesirable species include plant species not native to Kansas or Missouri.

Care shall be taken not to affect surrounding vegetation. The Contractor may be required to replant any vegetation affected by herbicide outside of targeted species.

A supply of chemical absorbent shall be maintained at the project site. Any chemical spills shall be properly cleaned up and reported to the Owner within 24 hours.

The Contractor shall maintain copies at the project site of all current pesticide applicator's licenses, herbicide labels, and MSDS's (Material Safety Data Sheets) for all chemicals utilized during completion of the work.

Herbicide may be applied using a backpack sprayer, a hand-held wick applicator, or a vehicle mounted high-pressure spray unit.

For bidding purposes, Contractor shall provide costs for three herbicide control treatments over an Owner-specified number of acres.

C Mowing

The Contractor shall mow all seeded areas to a height of 8-12" after vegetation in said areas reach a height of 30" and before non-native species go to seed during the first two growing seasons after planting.

2 For bidding purposes, Contractor shall provide costs for providing three mowings over an Owner-specified number of acres.

D Prescri ed Burning

Prescribed burning shall be the primary method of long-term ecological management and weed control of planting areas at the project site. Burning shall be conducted annually after the second full growing season or as directed by the Owner.

2 Prior to the commencement of prescribed burning, the Contractor shall compile a burn plan that outlines a plan of action, identifies contingencies, and lists the names and phone numbers of emergency agencies (fire department, police department, etc.). Proper notice of intent to burn shall be given.

The Contractor shall apply for and receive all required permits prior to the commencement of prescribed burning.

For bidding purposes, contractor shall provide costs for two burns over an Owner-specified number of acres.



E Clean-Up Remo al and Repair

Clean-Up: The work area shall be kept free of debris by the Contractor. At no time shall empty herbicide containers, trash, or other material be allowed to accumulate at the project site. All tools shall be kept in appropriate carrying cases, toolboxes, etc. Parking areas, roads, sidewalks, paths, and paved areas shall be kept free of mud and dirt.

2 Remo al: After work has been completed remove tools, empty containers, and all other debris generated by the Contractor.

Repair: Repair any damages caused by the Contractor during completion of the work described in this Section. Said damages may include, but are not limited to, tire ruts in the ground, damage to lawn areas, damage to trails, etc. The Contractor shall be liable for remedying damages to plant materials and property at no cost to the Owner caused by Contractor negligence during completion of the work.

Inspection: At the request of the Engineer, the Contractor shall schedule an inspection with the Owner to review the work completed by the Contractor pursuant to this section.

Acceptance and Guarantee: Final acceptance: Management shall be considered 100% complete after the Contractor has complied with all parts of this section.

900 Odds Ends

A Maintenance:

General: Maintain all components of the structure, starting with the clearing operations and continuing for 30 calendar days after all planting is complete and approved by the Engineer.

2 Work Included:

a Maintenance shall include erosion and sediment control. Construction operations will be carried out in such a manner that erosion will be controlled and water and air pollution minimized. State and local laws concerning pollution abatement will be followed.

Maintenance shall include grading all borrow areas to provide proper drainage and left in a slightly better condition. All exposed surfaces of the embankment, spillway, spoil and borrow areas, and berms shall be stabilized by seeding, limin, fertilizing, and mulching.

c Maintenance shall include all watering, weeding, cultivating, spraying, and pruning necessary to keep the plant materials in a healthy growing condition and to keep the planted areas neat and attractive throughout the maintenance period.

d Provide all equipment and means for proper application of water to planted areas.

e Protect all planted areas against damage, including erosion and trespassing, by providing and maintaining proper safeguards.

Replacements:

a At the end of the maintenance period, all plant material shall be in a healthy growing condition.

During the maintenance period, should the appearance of any plant indicate weakness and probability of dying, immediately replace that plant with a new and healthy plant of the same type and size without additional cost to the Engineer.

Extension of Maintenance Period: Continue the maintenance period at no additional cost to the Owner until all previously noted deficiencies have been corrected, at which time the final inspection shall be made.



B Acceptance:

The Contractor shall guarantee 80% survival of tree and shrub planting stock and 95% herbaceous.

2 Ninety days after planting, after “leaf-out”, a final inspection shall be made by the Contractor and the Engineer.

The Contractor shall satisfactorily replace any seedlings or shrubs up to 80% of the total number specified herein and up to 95% of the total area of herbaceous planting. With this replacement, as approved by the Engineer, the Contractor shall be issued a letter of acceptance for work covered by this Section of the Specifications in accordance with applicable provisions stated in the Special Provisions.

Clean-Up: General: During the progress of this work, and upon completion, thoroughly clean the project area and remove and properly dispose of all resultant dirt, debris and other waste materials.

## RECOMMENDED NATIVE PLANT MATERIALS FOR BMPs

| Plant Species | Annual/Perennial | Cool/Warm or 1st Flower | Local or Regional | Short/Medium/Tall | Leaf/Stem/Flower Color | Moist/Wet/Salt Tolerant | Riparian Buffer | Dry Swale | Wet Swale | Filter Strip | Infiltration Basin | Infiltration Trench | Sand Filter | Pervious Pavement | Bioretention | Rain Garden | ED Wetland | Phased Const. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***UPLANDS*** | | | | | | | | | | | | | | | | | | |
| ***GRAMINOIDS*** | | | | | | | | | | | | | | | | | | |
| Big Bluestem (Andropogon gerardii) | P | W | L | T | G | M | | | | | | | | | | | | |
| Side Oats Grama (Bouteloua curtipendula) | P | W | L | M | P/G | D/M | | | | | | | | | | | | |
| Blue Grama (Bouteloua gracilis) | P | W | R | S | BG | D | | | | | | | | | | | | |
| Hairy Grama (Bouteloua hirsuta) | P | W | R | S | BG | D | | | | | | | | | | | | |
| Woodland Brome Bromus pubescens | P | C | L | M | G | M | | | | | | | | | | | | |
| Buffalograss (Buchloe dactyloides) | P | W | R | S | BG/G | D/M/S | | | | | | | | | | | | |
| Woodland Sedge (Carex blanda) | P | C | L | S/M | GR | D/M | | | | | | | | | | | | |
| Mead s Sedge (Carex meadii) | P | C | L | S | GR | D | | | | | | | | | | | | |
| Pest Sedge (Carex molesta) | P | C | L | S/M | GR | D/M | | | | | | | | | | | | |
| Wood Sedge (Carex rosea) | P | C | R | S | GR | M/W | | | | | | | | | | | | |
| Pointed Broom Sedge (Carex scoparia) | P | C | R | M | BR | M/W | | | | | | | | | | | | |
| Woodland Sedge (Carex sparganioides) | P | C | R | S/M | GR | M | | | | | | | | | | | | |
| Canada Wildrye (Elymus canadensis) | P | C | L | T | G | D/M | | | | | | | | | | | | |
| Virginia Wildrye (Elymus virginicus) | P | C | L | M | G | M | | | | | | | | | | | | |
| Bottlebrush Grass Hystrix patula (Elymus hystrix) | P | C | R | M | G | M | | | | | | | | | | | | |
| Switchgrass (Panicum virgatum) | P | W | L | T | G | M/S | | | | | | | | | | | | |
| Western Wheatgrass (Pascopyrum smithii) | P | C | R | M | G/ G | M/S | | | | | | | | | | | | |
| Little Bluestem (Schi achyrium scoparium) | P | W | L | M | BG/G | D/M | | | | | | | | | | | | |
| Indian Grass (Sorghatrum nutans) | P | W | L | T | G | D/M | | | | | | | | | | | | |
| Prairie Cordgrass (Spartina pectinata) | P | W | L | T | G/BG | M/S | | | | | | | | | | | | |
| Prairie Dropseed (Sporobolus heterolepsis) | P | W | L | M | G | D/M | | | | | | | | | | | | |

| ***FORBS*** | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Meadow Garlic<br>(Allium canadense) | P | M | R | S | P | D/M | | | | | | | | | | | | |
| Leadplant<br>(Amorpha canescens) | P | M | L | M | B | M | | | | | | | | | | | | |
| Thimbleweed<br>(Anemone cylindrica) | P | M | R | S | G | D/M | | | | | | | | | | | | |
| Wild Columbine<br>(A  uilegia canadensis) | P | E | L | M | R | D/M | | | | | | | | | | | | |
| Common Milkweed<br>(Asclepias syriaca) | P | E | L | M | P | M | | | | | | | | | | | | |
| Buttererfly Milkweed<br>(Asclepias tuberosa) | P | E | L | M | OR | D/M | | | | | | | | | | | | |
| Whorled Milkweed<br>(Asclepias verticillata) | P | M | L | S | W | D/M | | | | | | | | | | | | |
| Sky Blue Aster<br>(Aster a  ureus) | P | L | L | M | B | D/M | | | | | | | | | | | | |
| Heath Aster<br>(Aster ericoides) | P | M | L | S/M | W | D/M | | | | | | | | | | | | |
| Smooth Blue Aster<br>(Aster laevis) | P | L | L | M | P/B | D/M | | | | | | | | | | | | |
| New England Aster<br>(Aster novae-angliae) | P | L | L | M/T | B | M/W | | | | | | | | | | | | |
| Willowleaf Aster<br>(Aster praealtus) | P | L | L | M/T | W/ | M | | | | | | | | | | | | |
| Silky Aster<br>(Aster sericeus) | P | L | R | S | P/B | D | | | | | | | | | | | | |
| Wild False Indigo<br>(Baptisia alba var. macrophylla) | P | E | L | M/T | W/ | M | | | | | | | | | | | | |
| Blue Wild Indigo<br>(Baptisia australis) | P | E | L | M | B | D/M | | | | | | | | | | | | |
| Cream False Indigo<br>(Baptisia bracteata) | P | E | L | S | W | D/M | | | | | | | | | | | | |
| American Bellflower<br>(Campanula americanum) | P | M | L | T | B | D/M | | | | | | | | | | | | |
| Partridge Pea<br>(Cassia fasciculata) | A | M | L | S | | D/M | | | | | | | | | | | | |
| Finger Coreopsis<br>(Coreopsis palmata) | P | M | L | M | | D/M | | | | | | | | | | | | |
| White Prairie Clover<br>(Dalea candida) | P | E | L | S | W | D/M | | | | | | | | | | | | |
| Purple Prairie Clover<br>(Dalea purpurea) | P | M | L | M | P | M | | | | | | | | | | | | |
| Illinois Bundleflower<br>(Desmanthus illinoensis) | P | M | L | M | G/BR | M | | | | | | | | | | | | |
| Showy Tick Trefoil<br>(Desmodium canadense) | P | M | L | S/M | P | M/D | | | | | | | | | | | | |
| Illinois Tick Trefoil<br>(Desmodium illinoense) | P | M | L | S/M | P | M/D | | | | | | | | | | | | |
| Purple Coneflower<br>(Echinacea purpurea) | P | M | R | M | P | M | | | | | | | | | | | | |
| Pale Purple Coneflower<br>(Echinacea pallida) | P | M | L | M | P | M | | | | | | | | | | | | |
| Rattlesnake Master<br>(Eryngium yuccifolium) | P | M | L | M | W | D/M | | | | | | | | | | | | |
| oe Pyeweed<br>(Eupatorium maculatum) | P | M | L | M | P | M/W | | | | | | | | | | | | |
| Flowering Spurge<br>(Euphorbia corollata) | P | M | L | S | W | D/M | | | | | | | | | | | | |
| Cream Gentian<br>(Gentiana alba) | P | L | R | M | W | D/M | | | | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Snee eweed<br>(Helenium autumnale) | P | L | R | S | | M/W | | | | | | | | | | | | |
| Maximillian Sunflower<br>(Helianthus maximillianii) | P | L | L | T | | M | | | | | | | | | | | | |
| Stiff Sunflower<br>(Helianthus rigidus or H. pauciflorus) | P | L | L | T | | D/M | | | | | | | | | | | | |
| Sawtooth Sunflower<br>(Helianthus grosseserratus ) | P | L | L | T | | M/W | | | | | | | | | | | | |
| False Sunflower<br>(Heliopsis helianthoides) | P | M | R | M | | D/M | | | | | | | | | | | | |
| Alum Root<br>(Heuchera richardsonii) | P | M | L | S | GR | D/M | | | | | | | | | | | | |
| Round-headed Bush Clover<br>(Lespede a capitata) | P | M | L | M | B | D/M | | | | | | | | | | | | |
| Rough Bla ing Star<br>(Liatris aspera) | P | L | L | M | P/R | D/M | | | | | | | | | | | | |
| Prairie Bla ingstar<br>(Liatris pycnostachya) | P | M | L | M | P/R | M | | | | | | | | | | | | |
| Great Blue Lobelia<br>(Lobelia siphilitica) | P | L | L | M | B | M/W | | | | | | | | | | | | |
| Wild Bergamot<br>(Monarda fistulosa) | P | M | L | M/T | P/B | D/M | | | | | | | | | | | | |
| Large-fruited Evening Primrose<br>(Oenothera macrocarpa) | P | M | L | S | | D | | | | | | | | | | | | |
| Showy Evening Primrose<br>(Oenothera speciosa) | P | E | L | S | W | D/M | | | | | | | | | | | | |
| Smooth Penstemon<br>(Penstemon digitalis) | P | E | L | M | W | M/W | | | | | | | | | | | | |
| Large-flowered Beard Tongue<br>(Penstemon grandiflorus) | P | E | R | M | P/B | D | | | | | | | | | | | | |
| Downy Phlox<br>(Phlox pilosa) | P | E | R | S | P | D/M | | | | | | | | | | | | |
| Prairie Cin uefoil<br>(Potentilla arguta) | P | M | R | S | | D/M | | | | | | | | | | | | |
| Slender Mountain Mint<br>(Pycanthemum tenuifolium) | P | M | L | S | W | D/M | | | | | | | | | | | | |
| ellow Coneflower<br>(Ratibida pinnata) | P | M | L | M | | D/M | | | | | | | | | | | | |
| Black-eyed Susan<br>(Rudbekia hirta) | A | E | L | M | | M | | | | | | | | | | | | |
| Cut-leaf Coneflower<br>(Rudbeckia laciniata) | P | L | L | T | | D/M | | | | | | | | | | | | |
| Compass Plant<br>(Silphium laciniatum) | P | M | L | T | | D/M | | | | | | | | | | | | |
| Cup Plant<br>(Silphium perfoliatum) | P | M | L | T | | M/W | | | | | | | | | | | | |
| Blue-eyed Grass<br>(Sisyrinchium campestre) | P | E | R | S | B | D | | | | | | | | | | | | |
| False Solomon s Seal<br>(Smilacina racemosa) | P | E | L | S/M | W | D/M | | | | | | | | | | | | |
| Canada Goldenrod<br>(Solidago canadensis) | P | L | L | T | | M | | | | | | | | | | | | |
| Old Field Goldenrod<br>(Solidago nemoralis) | P | L | L | S | | D | | | | | | | | | | | | |
| Stiff Goldenrod<br>(Solidago rigida) | P | L | L | M/T | | D/M | | | | | | | | | | | | |
| Showy Goldenrod<br>(Solidago speciosa) | P | L | R | T | | M | | | | | | | | | | | | |
| Germander, Wood Sage<br>(Teucrium canadense) | P | M | L | M | W/P | M | | | | | | | | | | | | |
| Purple Meadow Rue<br>(Thalictrum dasycarpum) | P | E/M | L | M | P | M/W | | | | | | | | | | | | |
| Prairie Spiderwort<br>(Tradescantia bracteata) | P | E | R | S | B | D/M | | | | | | | | | | | | |
| Ohio Spiderwort<br>(Tradescantia ohiensis) | P | E | L | M | B | D/M/W | | | | | | | | | | | | |
| Hoary Vervain<br>(Verbena stricta) | P | E | L | M | P/P | D/M | | | | | | | | | | | | |
| Heart-leaved Alexander<br>( i ia aptera) | P | E | R | S | | D/M | | | | | | | | | | | | |
| Golden Alexanders<br>( i ia aurea) | P | E | L | M | | M/W | | | | | | | | | | | | |

| WETLAND SPECIES | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***GRAMINOIDS*** | | | | | | | | | | | | | | | | | | |
| Wild Calamus (Acorus calamus) | P | E | R | M | W | W | | | | | | | | | | | | |
| Blue  oint Grass (Calamagrostis canadensis) | P | C | R | M/T | GR/ | M/W | | | | | | | | | | | | |
| Crested Sedge (Carex cristatella) | P | C | L | M | BR | M/W | | | | | | | | | | | | |
| Frank s Sedge (Carex frankii) | P | C | L | M | BR | M/W | | | | | | | | | | | | |
| Bottlebrush Sedge (Carex hystricina) | P | C | R | M | BR | M/W | | | | | | | | | | | | |
| Fox Sedge (Carex vulpinoidea) | P | C | L | S/M | GR | M | | | | | | | | | | | | |
| Saltgrass (Distichlis stricta) | P | W | R | S | G | M/S | | | | | | | | | | | | |
| Barnyard Grass (Echinochloa muricata) | P | W | L | M | GR | M/W | | | | | | | | | | | | |
| Blunt Spikerush (Eleocharis obtusa) | P | C | L | S | BR | M/W | | | | | | | | | | | | |
| Pale Spikerush (Eleocharis macrostachya) | P | C | R | S | BR | M/W | | | | | | | | | | | | |
| Fowl Manna Grass (Glyceria striata) | P | W | L | M/T | GR | W | | | | | | | | | | | | |
| Blueflag (Iris virginica) | P | C | R | S/M | B | M/W | | | | | | | | | | | | |
| Path Rush ( uncus interior) | P | C | L | S | BR | M/W | | | | | | | | | | | | |
| Torrey s Rush ( uncus torreyi) | P | C | R | S | BR | M/W | | | | | | | | | | | | |
| Rice Cutgrass (Leersia ory  oides) | P | C | L | S | GR | M/W | | | | | | | | | | | | |
| Dark Green Rush (Scirpus atrovirens) | P | C | L | M | GR | M/R | | | | | | | | | | | | |
| Softstem Bulrush (Scirpus validus) | P | C | L | T | GR | M/W | | | | | | | | | | | | |
| River bulrush (Scirpus fluviatilis) | P | C | R | T | GR | M/W | | | | | | | | | | | | |
| Common Bur Reed (Sparganium eurycarpum) | P | C | R | M/T | BR | W | | | | | | | | | | | | |
| ***FORBS*** | | | | | | | | | | | | | | | | | | |
| Canada anemone (Anemone canadensis) | P | E | L | S | W | M/W | | | | | | | | | | | | |
| Swamp Milkweed (Asclepias incarnata) | P | M | R | T | P/P | M/W | | | | | | | | | | | | |
| Nodding Beggar-ticks (Bidens cernuus) | P | M | L | M | | W | | | | | | | | | | | | |
| Water Hemlock (Cicuta maculata) | P | L | L | T | | W | | | | | | | | | | | | |
| Boneset (Eupatorium perfoliatum) | P | L | L | T | W | W | | | | | | | | | | | | |
| Cardinal Flower (Lobelia cardinalis) | P | M | L | M | R | M/W | | | | | | | | | | | | |
| Common Water Horehound (Lycopus americanus) | P | M | L | S | W | W | | | | | | | | | | | | |
| Winged Loosestrife (Lythrum alatum) | P | M | L | S | B/P | W | | | | | | | | | | | | |
| Field Mint (Mentha arvensis) | P | M | L | S | W | M/W | | | | | | | | | | | | |
| American Lotus (Nelumbo lutea) | P | M | R | S | W | W | | | | | | | | | | | | |
| Smartweed (Polygonum spp.) | P | EML | L | S/T | BR | M/W | | | | | | | | | | | | |
| Common Mountain Mint (Pycnanthemum virginianum) | P | M | R | M | W | M/W | | | | | | | | | | | | |
| Arrowhead (Sagittaria latifolia) | P | M | L | S/M | W | M/W | | | | | | | | | | | | |
| Hemlock Water Parsnip (Sium suave) | P | M | R | T | GR/W | M/W | | | | | | | | | | | | |
| Blue Vervain (Verbena hastata) | P | M | L | S | P/B | M/W | | | | | | | | | | | | |
| Iron Weed (Vernonia fasciculata) | P | L | L | M | R/P | M/W | | | | | | | | | | | | |
| Culver s Root (Veronicastrum virginicum) | P | M | L | M/T | W | M/W | | | | | | | | | | | | |

| ***TREES*** | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Silver Maple<br>(Acer saccharinum) | P | | R | 80 | R | M/W/S | | | | | | | | | | | | |
| River Birch<br>(Betula nigra) | P | | R | 50 | Br | M/W | | | | | | | | | | | | |
| Shagbark Hickory<br>(Carya ovata) | P | | L | 60-80 | G | D/M | | | | | | | | | | | | |
| Hackberry<br>(Celtis occidentalis) | P | | L | 45-80 | G | D/M | | | | | | | | | | | | |
| Red bud<br>(Cercis canadensis) | P | | L | 30 | Pk/P | D/M | | | | | | | | | | | | |
| Ha elnut<br>(Corylus americana) | P | | L | 10-15 | Br | D/M | | | | | | | | | | | | |
| White Ash<br>(Fraxinus americanum) | P | | L | 65-95 | W | D | | | | | | | | | | | | |
| Green Ash<br>(Fraxinus pennsylvanica subintegerrima) | P | | L | 60 | G | M/W | | | | | | | | | | | | |
| Black Walnut<br>( uglans nigra) | P | | L | 70 | W | D/M | | | | | | | | | | | | |
| Eastern Red Cedar<br>( uniperus virginiana) | P | | L | 50 | G/ | D/M/S | | | | | | | | | | | | |
| Sycamore<br>(Platanus occidentalis) | P | | L | 90 | W | M/W | | | | | | | | | | | | |
| Eastern Cottonwood<br>(Populus deltoides) | P | | L | 70-90 | | D/M/S | | | | | | | | | | | | |
| Black Cherry<br>(Prunus serotina) | P | | L | 60-90 | W | D/M | | | | | | | | | | | | |
| White Oak<br>( uercus alba) | P | | L | 60-100 | Br | D | | | | | | | | | | | | |
| Bur Oak<br>( uercus macrocarpa) | P | | L | 70-90 | Br | M/S | | | | | | | | | | | | |
| Pin Oak<br>( uercus palustris) | P | | L | 50-75 | Br | M/W/S | | | | | | | | | | | | |
| Red Oak<br>( uercus rubra) | P | | L | 70 | Br | D/M | | | | | | | | | | | | |
| Basswood<br>(Tilia americana) | P | | L | 50 | | D/M | | | | | | | | | | | | |
| Red Elm<br>(Ulmus rubra) | P | | L | 70 | Br | D/M | | | | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***SHRUBS AND VINES*** | | | | | | | | | | | | | | | | | | |
| New  ersey Tea (Ceanothus americanus) | P | E | L | 3-6 | G/BR | D/M | | | | | | | | | | | | |
| Buttonbush (Cephalanthus occidentalis) | P | | L | 15 | W | M/W | | | | | | | | | | | | |
| Rough-leaved Dogwood (Cornus drummondii) | P | | L | 20 | W | D/M | | | | | | | | | | | | |
| Gray Dogwood (Cornus racemosa) | P | | R | 15 | W | D/M | | | | | | | | | | | | |
| Red-osier Dogwood (Cornus stolonifera) | P | | R | 3-19 | W | D/M | | | | | | | | | | | | |
| Wild Plum (Prunus americana) | P | | L | 20-30 | W | D/M | | | | | | | | | | | | |
| Chokecherry (Prunus virginiana) | P | | L | 6-10 | W | D | | | | | | | | | | | | |
| Smooth Sumac (Rhus glabra) | P | | L | 6-15 | R | D/M | | | | | | | | | | | | |
| Sandbar Willow (Salix exigua) | P | | L | 18 | GR/ | M/ | | | | | | | | | | | | |
| Elderberry (Sambucus canadensis) | P | | L | 12 | W | M | | | | | | | | | | | | |
| Coralberry, buckbrush (Symphocarpus orbiculatus) | P | | L | 4-6 | P | D/M | | | | | | | | | | | | |

Life Cycle:  A – Annual; B – Biennial; or P – Perennial

Growth Height:  S – Short, < 2 ft.; M – Medium, 2-4 ft.; T – Tall, >4 ft.  Tree and shrub heights are given.

Color of Flower:  B – Blue; BG – Blue Green; Br - Brown; G – Green; OR – Orange; P – Purple; PK – Pink; R – Red; W – White; or Y – Yellow

Site Tolerance:  D – Dry;  M – Moist; S – Salt; or W - Wet

**Graminoids:** grass-like species including grasses, sedges, bulrushes, spikerushes, rushes, irises, bur reed, etc.

**Season: for Graminoids**  C--Cool, W--Warm

**1st  Flowering Date for Forbs:**
E or Early--before  une 1;
M or Mid--  une 1 to  uly 31;
L or Late--August 1 and beyond

**Occurrence within 50-mile radius of KCMO**
L or Local: found in  50  of counties
R or Regional: found in  50 , but  10  of counties

# Appendix B

## Pollution Controls for “Hot Spots”

# TABLE OF CONTENTS



# LIST OF TABLES

# B. POLLUTION CONTROLS FOR HOT SPOTS

## B.1 Summary

This appendix describes stormwater pollution controls for sites that generate or may generate pollutants.

To Use This Appendix:

- Determine if the project has any characteristics or site uses listed in Section B.2.0
- If so, go to the applicable section for that characteristic or site use, and follow the instructions to design pollution controls for the project.

## B Introduction and Applica ility

Some site characteristics and uses may generate pollutants or levels of pollution not addressed solely by implementing pollution reduction measures described in Sections 7, 8, and 9. Site characteristics and uses in this appendix are potential sources of chronic loadings or acute releases of pollutants: oil and grease, hydrocarbons, heavy metals, toxic compounds, solvents, abnormal pH levels, nutrients, organics, bacteria, and suspended solids. This appendix offers pollution controls to manage these pollutants at their sources.

Section B.2.0 lists the site uses and characteristics subject to the requirements of this appendix. Sections B.2.4 through B.2.11 provide detailed information about the recommended pollution controls.

These pollution controls apply to all new development and redevelopment projects with the defined uses or characteristics listed in Section B.2.0. With cumulative improvements, only those areas of a structure being disturbed under the permit should undergo the structural changes identified in the pollution controls.

The pollution controls are *in addition to* the selected BMP package determined in accord with Section 4.

## B 2 Site Uses and Characteristics that Trigger Pollution Controls

Projects with the following site uses and characteristics are subject to the requirements of this appendix:

- Fuel Dispensing Facilities (Section B.2.4)
- Aboveground Storage of Liquid Materials (Section B.2.5)
- Solid Waste Storage Areas, Containers, and Trash Compactors (Section B.2.6)
- Exterior Storage of Bulk Materials (Section B.2.7)
- Material Transfer Areas and Loading Docks (Section B.2.8)
- Equipment and Vehicle Washing Facilities (Section B.2.9)
- Covered Vehicle Parking Areas (Section B.2.10)
- High-Use Vehicle and Equipment Traffic Areas, Parking, and Vehicle Storage (Section B.2.11)
- Dog Kennels / Doggie Day Care, and Veterinary Clinics

## B 2 Goals for Pollution Controls

The pollution control requirements seek the following goals:

- Prevent stormwater pollution by eliminating pathways that may introduce pollutants into stormwater.
- Protect soil, groundwater, and surface water by capturing acute releases and reducing chronic contamination of the environment.

- Segregate stormwater and wastewater flows to minimize additions to the sanitary and combined sewer systems.
- Direct wastewater discharges and areas with potential for consistent wastewater discharges (such as vehicle washing facilities) to the sanitary or combined sewer system.
- Provide an approved method of containment or disposal to areas that do not receive flow regularly or require water use and have the potential for acute releases or accidental spills.
- Contain spills onsite.
- Emphasize structural controls over operational procedures, because structural controls are not operator dependent and are considered to provide more permanent and reliable pollution control. Proposals for operation-based pollution controls must speak to the long-term viability of the maintenance program.
- Furnish permanent structural solutions for the range of impacts that could result from multiple-site uses and tenant turnover.

## B 2 2 Multiple Pollution Control Requirements

Applicants should address all site characteristics and uses listed in Sections B.2.4 through B.2.11. For example, if a development includes both a fuel dispensing area and a vehicle washing facility, the pollution controls in both Sections B.2.4 and B.2.9 apply.

## B 2 Additional Requirements

Compliance with this appendix does not relieve the applicant of other applicable local, state, or federal regulatory or permit requirements. This appendix complements any additional requirements its recommendations do not oppose, exclude, or replace those requirements. In case of a conflict, apply the more stringent local, state, or federal regulation(s).

Some common requirements are as follows:

### *B. . . Spill Response Supplies*

Spill response supplies such as absorbent material and protective clothing should be available at all potential spill areas. Employees should be familiar with the site's operations and maintenance plan that should include proper spill cleanup procedures.

### *B. . . Stormwater and astewater Discharge Permits*

Some facilities should obtain a NPDES stormwater permit before discharging to the storm sewer system or to waters of the state. Applicants also should acquire an industrial wastewater permit for discharges to the sanitary sewer system. Facilities subject to these requirements are generally commercial or industrial. Typical discharges include process wastewater, cooling water, or other discharges generated by some pollution controls described in this appendix that drain to a public sewer system (storm, sanitary, or combined). Contact the governing jurisdiction for a list of current discharge requirements.

### *B. . . Other Local State and Federal Regulations*

The recommendations in this appendix do not exclude or replace requirements of other applicable codes or regulations, such as: hazardous substance storage requirements; the spill prevention control and containment (SPCC) regulations of 40 Code of Federal Regulations (CFR) 112 (U.S. Environmental Protection Agency EPA ); the Resource Conservation and Recovery Act (RCRA); or any other applicable local, state, or federal regulations or permit requirements.

## B 2 uel Dispensing acilities

The following sections provide information about facilities that dispense fuels.

### *B. . . Applicability*

This section applies to all development where vehicles, equipment, or tanks are refueled on the premises whether a large-sized gas station, a single-pump maintenance yard, or a small-sized fueled tank.

A fuel dispensing facility is defined as the area where fuel is transferred from bulk storage tanks to vehicles, equipment, and mobile containers (including fuel islands, aboveground or belowground fuel tanks, fuel pumps, and the surrounding pad). Propane tanks are exempt from these recommendations.

### *B. . . Management Practices*

The following sections describe management practices for various circumstances.

#### *B. . . . Cover*

Cover the fuel dispensing area with a permanent canopy, roof, or awning to prevent contact between precipitation and the fueling activity area. Direct precipitation from the cover to a stormwater disposal system that meets all applicable code requirements. Covers 10 feet high or less should have a minimum overhang of 3 feet on each side. Covers higher than 10 feet should have a minimum overhang of 5 feet on each side. In each instance, measure the overhang from the perimeter of the hydraulically isolated fueling activity area.

#### *B. . . . Pavement*

Place a paved fueling pad under and around the fueling activity area. Size the pad to cover the activity area including area for fueling vehicles or equipment.

Gasoline and other materials can react with asphalt pavement to release oils from the pavement; therefore, pave the area with hydraulic concrete. If the area is already paved with asphalt, apply an asphalt sealant to the pavement surface. Maintain the paved surface to prevent gaps and cracks.

#### *B. . . . Drainage*

Hydraulically isolate the paved area beneath the cover using grading, berms, or drains. This prevents uncontaminated stormwater from running onto the area and carrying away pollutants. Direct drainage from the hydraulically isolated area to an approved sanitary sewer or authorized pretreatment facility. Direct surrounding runoff away from the hydraulically isolated fueling pad to a stormwater disposal system that meets all stormwater management recommendations of this appendix.

#### *B. . . . Sedimentation Manhole ith Tee Outlet*

Install a sedimentation manhole with tee outlet on the discharge line of the fueling pad before tying in the domestic waste line. The tee section should extend 18 inches below the outlet elevation, and include an additional 4 feet of dead volume below the tee to store oil and grease. Locate the manhole on private property.

#### *B. . . . Shut-Off Valves*

Before tying in the domestic waste line, install shut-off valves downstream of all applicable stormwater-quality facilities that serve the surrounding fueling activity areas, and downstream of the sedimentation manhole recommended for the fueling pad. Locate shut-off valves on private property.

## B 2 A o eground Storage of Liquid Materials

The following sections describe conditions required to store aboveground liquid materials.

*B. . .	Applicability*

This section applies to all developments with exterior storage of liquid chemicals, food products, waste oils, solvents, or petroleum products in aboveground containers equaling or exceeding 50 gallons. This includes permanent storage and temporary storage areas.

The recommendations do not apply to underground storage tanks or to businesses permitted by the state to treat, store, or dispose of regulated substances or wastes.

| Note: Storage of reacti e ignita le or flamma le liquids should comply with the Uniform ire Code |
|---|

*B. . .	Management Practices*

The following sections describe management practices for various circumstances.

*B. . . .	Containment*

Store and contain liquid materials so that if the container ruptures, the contents cannot move into a receiving system.

A device or structure to contain accidental spills should have enough capacity to capture a minimum of 110 percent of the product's largest container or 10 percent of the total volume of product stored whichever is larger.

*B. . . .	Cover*

Completely cover storage containers (other than tanks) so precipitation cannot contact them. Direct precipitation from the cover to a stormwater disposal system that meets all applicable code requirements. Covers 10 feet high or less should have a minimum overhang of 3 feet on each side. Covers higher than 10 feet should have a minimum overhang of 5 feet on each side. In each instance, measure the overhang from the perimeter of the hydraulically isolated fueling activity area.

Do not cover liquid storage tanks with a canopy or roof. However, when transferring liquids or making and breaking connections, completely cover with rain shields all taps, couplings, pumps, and other potential drip, spill, and leak-prone spots. Place drip pans under the rain shields. Reuse, recycle, or appropriately dispose of any materials collected in the drip pans and any soiled absorbent materials. Record disposal locations and dates as part of the facility's operations and maintenance log.

*B. . . .	Pavement*

A paved storage area is recommended. Size the paved area to cover the area intended for storage.

Gasoline and other materials can react with the asphalt pavement to release toxic oils from the pavement. Therefore, pave the area with hydraulic concrete. If the area is already paved with asphalt, apply an asphalt sealant to the pavement surface. Maintain the paved surface to prevent gaps and cracks.

When an exception to the requirement is allowed, stored material must be raised from the ground by pallets or similar methods, and provisions for spill control must be established.

*B. . . .	Drainage*

Hydraulically isolate all paved storage areas using grading, berms, or drains to prevent uncontaminated stormwater from entering a storage area.

*B. . . .	Covered Storage Areas*

Significant amounts of precipitation are not expected to accumulate in covered storage areas, and drainage facilities are not recommended for the contained area beneath the cover. The applicant electing to install drainage facilities should direct the drainage from the hydraulically isolated area to an approved sanitary sewer or authorized pretreatment facility.

*B. . . .    Uncovered Storage Areas  ith Containment*

Water accumulates in uncovered storage areas during and after rain. Do not drain any *contaminated* water from the area. Collect, inspect, and possibly test it before specifying proper disposal. Monitoring the stormwater characteristics and level of contamination may also be necessary.

Discharging to the sanitary sewer may require approval, and pretreatment may be necessary. Contact the governing jurisdiction for requirements.

*B. . . .    Additional Recommendations*

Additional recommendations are as follows:

- Covered storage areas: A shut-off valve may be recommended for the covered storage area, if the applicant elects to install drainage facilities to an approved sanitary sewer.
- Uncovered storage areas: Install a shut-off valve in the storage area to drain excess stormwater from the activity area. Direct it to the storm drainage facilities (*if clean*), or into the sanitary sewer, or to the authorized pretreatment facility (*if contaminated*). Keep the valve closed to contain any spills within the activity area, except when discharging excess stormwater.
- Storage of hazardous materials: Toxic, carcinogenic, or halogenated solvents stored in designated groundwater resource protection areas are subject to additional state and federal requirements.
- Storage of reactive, ignitable, or flammable liquids: When storing these materials, comply with the Uniform Fire Code. Pollution controls in this section are to complement, not oppose, current fire code requirements.

## B 2    Solid Waste Storage Areas  Containers  and Trash Compactors

The following sections furnish information about storing solid waste.

*B. . .    Applicability*

The recommendations in this section apply to all developments with facilities to store solid wastes (food and non-food) outdoors in one or more solid-waste storage areas. A solid-waste storage area is where solid waste containers are stored. Solid waste containers include compactors, dumpsters, and garbage cans (including those used to contain recyclable materials).

*B. . .    Management Practices*

The following sections describe management practices for various circumstances..

*B. . . .    Cover*

Permanent canopies, roofs, or awnings are recommended for solid waste storage areas containers. Construct them to cover the activity area so precipitation cannot contact stored waste materials. Direct precipitation from the cover to a stormwater disposal system that meets all applicable code requirements. Covers 10 feet high or less should have a minimum overhang of 3 feet on each side. Covers higher than 10 feet should have a minimum overhang of 5 feet on each side. In each instance, measure the overhang from the perimeter of the hydraulically isolated solid waste storage area.

Dumpsters and garbage cans used to store non-food solid waste do not require a permanent canopy, roof, or awning. Non-food solid wastes include refuse typically generated by a household or non-food-related business. Do not necessarily cover these areas structurally, but do cover them with lids. Use only leak-proof containers.

Dumpsters and garbage cans used to store food wastes and materials other than solid waste require permanent canopies , roofs, or awnings. Here ”solid waste” refers to fertilizers, chemicals, and animal wastes. Food waste refuse is typically generated by restaurants, food handlers, and other food industry businesses. Food waste includes foods not consumed by customers and excess or spoiled food.

Dumpsters and garbage cans used to store food wastes and materials other than solid wastes should be covered with permanent cover to prevent stormwater contact and minimize the quantity of stormwater entering the waste storage area. Hydraulically isolate the area beneath the cover from other portions of the site using grading, berms, or drains.

Trash compactors need not have permanent cover. But they are assessed an impervious area charge at sanitary rates for stormwater discharging to the sanitary system. The amout depends on annual rainfall data. Hydraulically isolate the area beneath the compactor from other portions of the site using grading, berms, or drains.

*B. . . .  Pavement*

Pave the area beneath the cover with asphalt or concrete, and meet all applicable code requirements. A paved waste storage area is recommended for waste storage areas with structural cover or use of trash compactor. Size the paved area to cover the area intended to store refuse or trash compactor(s) and associated equipment. Hydraulically isolate the area beneath the cover using grading, berms, or drains.

*B. . . .  Drainage*

Hydraulically isolate drainage beneath any covered area using berming, grading, or drains to prevent uncontaminated stormwater from running onto the area and carrying away pollutants. Direct drainage from the hydraulically isolated area to an approved sanitary sewer or authorized pretreatment facility. Direct surrounding runoff away from the hydraulically isolated waste storage area to a stormwater disposal system that meets all applicable code requirements.

## B 2  Exterior Storage of Bulk Materials

The following sections discuss how to store bulk materials in outside containers.

*B. . .  Applicability*

The recommendations in this section apply to developments that stockpile or store erodible materials in outside containers. This includes, but is not limited to, the following general categories:

- Pesticides and fertilizers
- Food items and wastes
- Scrap and recycling materials and yards
- Soil, sand, and other materials that increase total suspended solids (TSS) in stormwater (including contaminated soil)
- Raw by-product materials, waste, or final product.

Materials with any of the following characteristics are exempt from the recommendations of this section:

Have no measurable solubility or mobility in water and no hazardous, toxic, or flammable properties

Exist in a gaseous form at ambient temperature

Are contained in a manner that prevents contact with stormwater (excluding pesticides and fertilizers).

Exhi it B 2- (below) lists some common bulk materials. The list is separated into three categories based on risk assessments for each material stored: high-risk, low-risk, and exempt.

| TABLE B<br>Bulk Material Categories | | |
|---|---|---|
| High-Risk Bulk Materials<br>• Recycled materials with potential effluent<br>• Stored and processed food items<br>• Chalk or gypsum products<br>• Feedstock or grain<br>• Material byproducts with potential effluent<br>• Asphalt<br>• Fertilizer<br>• Pesticides<br>• Lime or lye or soda ash<br>• Animal or human wastes | Low-Risk Bulk Materials<br>• Recycled materials without potential effluent<br>• Scrap or salvage goods<br>• Metal<br>• Sawdust or bark chips<br>• Sand or dirt or soil (including contaminated soil piles)<br>• Material byproducts without potential effluent<br>• Unwashed gravel or rock<br>• Compost | Exempt Bulk Materials<br>• Washed gravel or rock<br>• Finished lumber<br>• Rubber and plastic products (hoses, gaskets, pipe, and so on)<br>• Clean concrete products (blocks, pipe, and so on)<br>• Glass products (new, non-recycled)<br>• Inert products |

*B. . .   Management Practices*

The following sections discuss how to manage bulk products in outside containers.

*B. . . .   Cover*

Cover low-risk bulk materials with a temporary plastic film or sheeting (at a minimum).

Permanently cover high-risk bulk materials with a canopy or roof to prevent stormwater contact and minimize the precipitation entering the storage area. Direct precipitation from the cover to a stormwater disposal system that meets all applicable code requirements. Covers 10 feet high or less should have a minimum overhang of 3 feet on each side. Covers higher than 10 feet should have a minimum overhang of 5 feet on each side. In each instance, measure the overhang from the perimeter of the hydraulically isolated fueling activity area.

*B. . . .   Pavement*

Low-Risk bulk material storage areas may or may not be paved.

High-risk bulk material storage areas should be paved beneath the structural cover.

Gasoline and other materials can react with asphalt pavement to release toxic oils from the pavement. Therefore, pave the area with hydraulic concrete. If the area is already paved with asphalt, apply an asphalt sealant to the pavement surface. Maintain the paved surface to prevent gaps and cracks that could contribute to soil contamination.

*B. . . .   Drainage*

Protect low-risk bulk material storage areas from precipitation and erosion if materials are erodible. If materials are erodible, place a containment barrier on at lease three sides of every stockpile to act as a barrier or filter for runoff.

For high-risk bulk material storage areas, hydraulically isolate the paved area beneath the structural using grading, berms, or drains to prevent uncontaminated stormwater from running onto the area and carrying away pollutants.

Since significant amounts of precipitation are not expected to accumulate in covered storage areas, drainage facilities are not recommended for the containment area beneath the cover.

*B. . . .   Additional Recommendations*

- Storage of pesticides and fertilizers may need to comply with specific regulations issued by the state.
- Sampling manholes or another suitable stormwater monitoring access point may be recommended to monitor stormwater runoff from the storage area. Certain types of storage activities and materials or proposed alternative pollution control may apply to this circumstance.
- Shut-off valves may be recommended for the structurally covered storage area if the applicant elects to install drainage facilities to an approved sanitary sewer.
- Storage of toxic, carcinogenic, or halogenated solvents (within designated groundwater protection areas) is subject to additional state and federal requirements.

## B 2   Material Transfer Areas and Loading Docks

*B. . .   Applicability*

The following sections provide information about material transfer areas and loading docks.

The recommendations in this section apply to all developments proposing to install new material transfer areas or structural alternatives to existing material transfer areas (such as access ramp regrading or leveler installations).

Two standard types of material transfer areas associated with buildings are: 1) Loading or unloading facilities with docks, and 2) large bay doors without docks. The recommendations apply to these material transfer areas and any other building access point(s) with both of the following characteristics:

- The area is designed with the size and width to accommodate a truck or trailer backing up to or into it.
- The area will receive or distribute materials to and from trucks or trailers.

The recommendations may not apply to areas used only for mid-sized to small-sized passenger vehicles and restricted (by lease agreements or other regulatory requirements) to storing, transporting, or using materials classified as domestic use. Examples of domestic uses include primary educational facilities (elementary, middle, or high school), buildings used for temporary storage (a lease agreement must be provided), and churches.

*B. . .   Management Practices*

The following sections discuss how to manage material transfer areas and loading docks.

*B. . . .   Cover*

- Existing and New Buildings with Loading Docks: Cover loading docks with a canopy, roof, or other permanent overhang that extends a minimum of 4 feet over the trailer or truck end. The cover should minimize the volume of precipitation discharged to the sanitary sewer or authorized pretreatment facility. Direct precipitation from the cover to a stormwater disposal system that meets all applicable code requirements.
- Bay Doors and Other Interior Transfer Areas: Conduct all transfer of materials with the truck or trailer end backed into the building a minimum of 5 feet (see additional recommendations below). An exterior cover is not necessary for these areas.

*B. . . .   Pavement*

Place a paved area underneath and around the loading and unloading activities. This reduces the potential for soil contamination that impacts groundwater and helps control any acute or chronic release of materials present in these areas.

Some materials can react with asphalt pavement to release oils from the pavement. Pave the area with hydraulic concrete. If the area is already paved with asphalt, apply an asphalt sealant to the pavement surface. Properly maintain the pavement surface to prevent gaps and cracks.

*B. . . .   Drainage*

- Loading Docks: Hydraulically isolate the first 3 feet of the paved area beneath the cover measured from the building or dock face using grading, berms, or drains to prevent uncontaminated stormwater from running into the area and carrying away pollutants. Direct drainage from the hydraulically isolated area to an approved sanitary sewer or authorized pretreatment facility. Direct surrounding runoff away from the hydraulically isolated loading dock area to a stormwater disposal system that meets all applicable recommendations of this appendix.
- Bay Doors and Other Interior Transfer Areas: Design bay doors and other interior transfer areas so stormwater does not enter the building. Grading or drains can accomplish this.

Because interior material transfer areas are not expected to accumulate precipitation, installation of floor drains is not necessary or recommended. Handle these areas with a dry mop or absorbent material. If interior floor drains are installed, they should be plumbed to an approved sanitary sewer or authorized pretreatment facility.

*B. . . .   Additional Recommendations*

- Bay doors and other interior transfer areas: These require a 10-foot “no obstruction zone” beyond the entrance within the building. This allows transfer of materials to occur with the truck or trailer end placed at least 5 feet inside the building, with an additional staging area of 5 feet beyond that. Clearly identify the “no obstruction” zone on the building plan at the time of permit application.
- Shut-off valve: This may be necessary for discharges to an approved sanitary sewer.
- Transport and handling of hazardous materials: Transport and handling of toxic, carcinogenic, or halogenated solvents are subject to additional state and federal requirements.

## B 2 9   Equipment and Vehicle Washing acilities

The following sections furnish information about equipment and vehicles washing facilities.

*B. . .   Applicability*

The recommendations in this section apply to all development with a designated equipment and vehicle washing or steam cleaning area. This includes smaller activity areas such as wheel washing stations. Residential sites are not included.

Development intended to store 10 or more fleet vehicles should include a designated vehicle washing area except if vehicles are routinely washed in an approved location.

*B. . .   Management Practices*

The following sections discuss how to manage equipment and vehicle washing facilities.

*B. . . .   Cover*

Cover the washing area with a permanent canopy or roof so precipitation cannot come in contact with the washing activity area. Direct precipitation from the cover to a stormwater disposal system that meets all applicable code requirements. Covers 10 feet high or less should have a minimum overhang of 3 feet on each side. Covers higher than 10 feet should have a minimum overhang of 5 feet on each side. In each instance, measure the overhang from the perimeter of the hydraulically isolated fueling activity area.

*B. . . .   Pavement*

Place a designated paved wash area underneath and around washing activity areas. Size the paved area to cover the activity area, including a place where the vehicle or piece of equipment is cleaned.

Some materials can react with asphalt pavement to release toxic oils from the pavement. Pave the area with hydraulic concrete. If the area is already paved with asphalt, apply an asphalt sealant to the pavement surface. Properly maintain the pavement surface to prevent gaps and cracks.

*B. . . .   Drainage*

Hydraulically isolate the paved area beneath the cover using grading, berms, or drains to prevent uncontaminated stormwater from running onto the area and carrying away pollutants. Direct drainage from the hydraulically isolated area to an approved sanitary sewer or authorized pretreatment facility. Direct surrounding runoff away from the hydraulically isolated washing pad to a stormwater disposal system that meets all applicable recommendations of this appendix.

*B. . . .   Oil Controls*

All vehicle and equipment washing activities should include oil controls. On-site wash recycling systems may be used for oil control, as long as they meet applicable effluent discharge limits for the sanitary sewer system.

*B. . . .   Exceptions*

- Permanent Cover: If a washing activity area is used generally to service oversized equipment that cannot maneuver under a roof or canopy (for instance, cranes, sail boats), a roof or canopy may not be necessary.
- Surface Stormwater: Because stockpile has the potential to erode, place a containment barrier on all four sides of every stockpile to prevent stormwater run-on and material runoff. Barriers can consist of concrete curbing, silt fencing, or other berming material   depending on the activity, size, and resources available.

## B 2   0   Co  ered   ehicle parking areas

The following sections deal with covered vehicle parking areas.

*B. .   .   Applicability*

The recommendations in this section apply to all development with a covered vehicle parking area, except single-family and duplex residential sites. Existing parking structures do not need retrofitting. New parking structures should meet these specifications.

*B. .   .   Drainage*

- Top Floor Drainage of a Multi-Level Parking Structure: Direct stormwater runoff from the top floor to a stormwater disposal system that meets all water quality recommendations of this appendix and any other applicable code requirements.
- Lower Floor Drainage of a Multi-Level Parking Structure: Since significant amounts of precipitation are not expected to accumulate in covered vehicle parking areas, drainage facilities are not recommended for the lower floors. If the applicant elects to install drainage facilities, direct the drainage from the lower floors to an approved sanitary sewer.
- Adjacent Uncovered Portions of the Site: Design surrounding uncovered portions of the site so stormwater does not enter the covered parking areas. This can be accomplished through grading or drains.

*B. . . Liquid Materials Stored in Aboveground Tanks*

Stormwater runoff and spills from some materials storage, use, or transportation areas have the potential to contribute chemical, physical, and biological pollutants to receiving systems; these include toxic substances, organic compounds, oil and grease, heavy metals, bacteria, nutrients, and suspended solids. These substances can enter the groundwater or surface water through acute releases or chronic loading. Potential pollutants can vary extensively in type and severity, depending on the characteristics of the stored material.

Hazardous materials are so defined if they or a constituent of them posses one of the following characteristics:

- Carcinogenity
- Toxicity
- Presence of halogenated solvent.

## B 2 High-Use Vehicle and Equipment Traffic Areas Parking and Vehicle Storage

The following sections provide information about high-use vehicle or high-risk-vehicle areas.

*B. . . Applicability*

The recommendations of this section apply to all types of vehicle and equipment traffic areas, parking lots, and vehicle storage (commercial, public, and private) with any of the following high-use or high-risk conditions:

- A commercial or industrial site that stores wrecked or impounded vehicles
- Sites with high likelihood of oil and grease releases (such as fast-food restaurants, vehicle repair shops, vehicle sales establishments, and vehicle-fueling service areas).

*B. . . Management Practices*

The following sections discuss how to manage high-use-vehicle or high-risk-vehicle areas.

- Pavement: Because of the potential for soil and groundwater contamination, all high-use or high-risk sites should be paved.

  Gasoline and other materials can react with asphalt pavement to release toxic oils from the pavement. Pave the area with hydraulic concrete. If the area is already paved with asphalt, apply an asphalt sealant to the pavement surface. Properly maintain the pavement surface to prevent gaps and cracks.

- Oil Water Separation: City will generally prohibit discharge of stormwater with a visible sheen to the storm sewer system. Together with pollution reduction facilities to meet the recommendations of this appendix, oil-water separators approved by the governing municipality may be recommended to provide oil control for these areas.

# Appendix C

## Analysis of Treatment System Preference

**ANAL SIS OF TREATMENT S STEM PERFORMANCE DISCLAIMER**

The BMP Database ( Database ) was developed as an account of work sponsored by the Water Environment Research Foundation (WERF), the American Society of Civil Engineers (ASCE) / Environmental and Water Resources Institute (EWRI), the American Public Works Association (APWA), the Federal Highway Administration (FHWA), and U.S. Environmental Protection Agency (EPA)(collectively, the Sponsors ). The Database is intended to provide a consistent and scientifically defensible set of data on Best Management Practice ( BMP ) designs and related performance. Although the individuals who completed the work on behalf of the Sponsors ( Pro ect Team ) made an extensive effort to assess the uality of the data entered for consistency and accuracy, the Database information and/or any analysis results are provided on an AS-IS basis and use of the Database, the data information, or any apparatus, method, or process disclosed in the Database is at the user s sole risk. The Sponsors and the Pro ect Team disclaim all warranties and/or conditions of any kind, express or implied, including, but not limited to any warranties or conditions of title, non-infringement of a third party s intellectual property, merchantability, satisfactory uality, or fitness for a particular purpose. The Pro ect Team does not warrant that the functions contained in the Database will meet the user s re uirements or that the operation of the Database will be uninterrupted or error-free, or that any defects in the Database will be corrected.

UNDER NO CIRCUMSTANCES, INCLUDING CLAIMS OF NEGLIGENCE, SHALL THE SPONSORS OR THE PRO ECT TEAM MEMBERS BE LIABLE FOR AN DIRECT, INDIRECT, INCIDENTAL, SPECIAL, OR CONSE UENTIAL DAMAGES INCLUDING LOST REVENUE, PROFIT OR DATA, WHETHER IN AN ACTION IN CONTRACT OR TORT ARISING OUT OF OR RELATING TO THE USE OF OR INABILIT TO USE THE DATABASE, EVEN IF THE SPONSORS OR THE PRO ECT TEAM HAVE BEEN ADVISED OF THE POSSIBILIT OF SUCH DAMAGES.

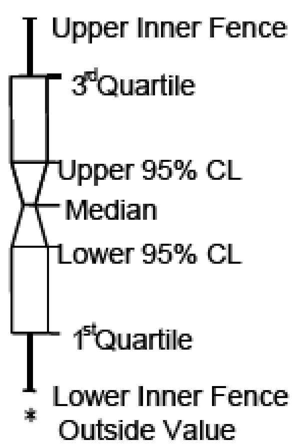
The Pro ect Team s tasks have not included, and will not include in the future, recommendations of one BMP type over another. However, the Pro ect Team s tasks have included reporting on the performance characteristics of BMPs based upon the entered data and information in the Database, including peer reviewed performance assessment techni ues. Use of this information by the public or private sector is beyond the Pro ect Team s influence or control. The intended purpose of the Database is to provide a data exchange tool that permits characteri ation of BMPs solely upon their measured performance using consistent protocols for measurements and reporting information. The Pro ect Team does not endorse any BMP over another and any assessments of performance by others should not be interpreted or reported as the recommendations of the Pro ect Team or the Sponsors.

Analysis of Treatment System Performance Introduction  The following summaries analy e available monitoring data drawn from the International Stormwater Best Management Practices (BMP) Database to determine whether any differences in treatment performance may be determined based on BMP category (e.g. detention basin, media filter, wetland basin, etc). These summaries focus on two separate data analyses:

- A data set composed of each BMP study s average effluent event mean concentrations (EMCs) over the entire respective monitoring period, grouped by BMP category.
- A data set comprised of all of the individual effluent EMCs, grouped by BMP category.

For each water  uality constituent examined, only those BMP studies reporting at least 3 influent and effluent EMCs were included in either data set. While this minimum threshold permits the actual calculation of the reported statistics (mean, median, percentiles, etc.), the robustness of such statistics is limited for these smallest samples.

The first data set (averaged EMCs)  weighs  the water  uality data for each individual BMP study e  ually (one average EMC value per BMP study) no matter the number of events monitored, thereby placing the emphasis of the evaluation on whether similar types of BMPs at a variety of different sites achieve comparable average effluent  uality. This analysis mutes the influence of individual events, and does not favor BMP studies that report a relatively large number of EMCs. The second analysis compares the distribution of effluent water  uality from individual events by BMP category, thereby providing greater weight to those BMPs for which there are a larger number of EMCs reported. This represents an important distinction between the two analyses, and it is essential that interpretation of the performance summaries reflect how the data has been compiled and presented.



Notched box-and-whisker plots are used to graphically display the categori ed distributions from both datasets. The notches encompass the 95 confidence interval of the median (averaged EMCs or individual EMCs, depending on the analysis) and provide a graphical, nonparametric means of assessing the difference between the centers of multiple distributions. A logarithmic scale was determined to be best suited for plotting the data. The log-scale boxplots were created utili ing the following method to calculate the upper and lower confidence levels:

1) The natural logs of the effluent values (averaged EMCs or individual EMCs, depending on the analysis) for a given BMP category are sorted in ascending order.
2) The upper and lower uantiles (i.e. the 75th and 25th percentiles) are calculated, following Tukey (1977).
3) The confidence interval of the median is calculated based on the upper and lower uantiles, following McGill et al (1978).
4) The median and confidence interval is translated back to arithmetic space. These values are used to delineate the upper and lower bounds of the notch on the boxplots.

For both the distributions of averaged EMCs by BMP category and the distributions of individual EMCs by BMP category, the arithmetic values of the median and associated upper confidence level (UCL) and lower confidence level (LCL) are provided in the table that accompanies each summary. An assessment was also made of the difference between the median effluent values and the corresponding influent values for both data sets. This assessment is critical, because it provides a measure of whether or not the data indicate a statistically significant difference in pollutant levels between the influent and effluent. To perform this test, the median, UCL and LCL for influent values were calculated in the same manner as for the effluent. A significant difference between the median influent and effluent values is assumed if their respective confidence intervals do not overlap; otherwise, the difference is not considered statistically significant. The same test may be performed graphically by plotting influent and effluent notched boxplots side-by-side and comparing the confidence limits visually.

In many instances, no significant difference between influent and effluent medians was determined. Therefore, it is not possible to determine with any certainty whether the BMP had an effect or simply that the characteristics of the runoff treated (for example, low influent concentrations) govern the distribution of effluent values. Where the analysis of significant difference indicates that effluent levels are greater than influent, this is noted in the text and as a footnote to the tabulated values.

## References

McGill, R., .W. Tukey, and W.A. Larsen, "Variations of Boxplots," *The American Statistician*, Vol. 32, pp.12-16, 1978.

Tukey, . W. (1977). *Exploratory data analysis*. Reading, MA: Addison-Wesley Publishing Company.

## Analysis of Treatment System Performance    Solids

Total Suspended Solids (mg/L)  Total suspended solids (TSS) represents the most widely reported stormwater constituent in the International Stormwater Best Management Practices (BMP) Database. Information regarding particle si  e distributions or settling velocities among the studies included in the database is very limited, and no distinction based on these factors is made between BMP studies analy  ed.

*Analysis of Mean Effluent TSS Concentration by BMP Category  (one value per BMP Study)*

Average effluent TSS concentrations are significantly lower than average influent for all BMP categories analy  ed except hydrodynamic devices and wetland basins.  Note that the limited number of wetland channel BMPs analy  ed reduces the ability to statistically determine results for this category. Median averaged effluent concentrations for detention basins, biofilters and hydrodynamic devices are above 35 mg/L, while those for media filters, retention ponds, wetland basins and wetland channels range between approximately 15 to 24 mg/L.

Media filters, biofilters and hydrodynamic devices are all primarily flow-through systems (i.e. no significant detention of flows).  Of these, media filters exhibit the lowest averaged effluent.  Of the storage-type categories, those which include some kind of permanent pool (retention ponds, wetland basins and wetland channels) exhibit lower effluent levels (only retention ponds achieves a strongly significant difference between influent and effluent).

*Analysis of Effluent TSS Concentrations  by BMP Category  (all individual EMCs included in dataset)*

Median effluent TSS EMCs for detention basins and hydrodynamic devices are notably higher than for the other BMP categories analy  ed.  In general, lower effluent TSS concentrations are observed for those categories that provide extended storage of stormwater flows (retention ponds, wetland basins).

SEE INTRODUCTION FOR
INTERPRETATION OF THESE FIGURES

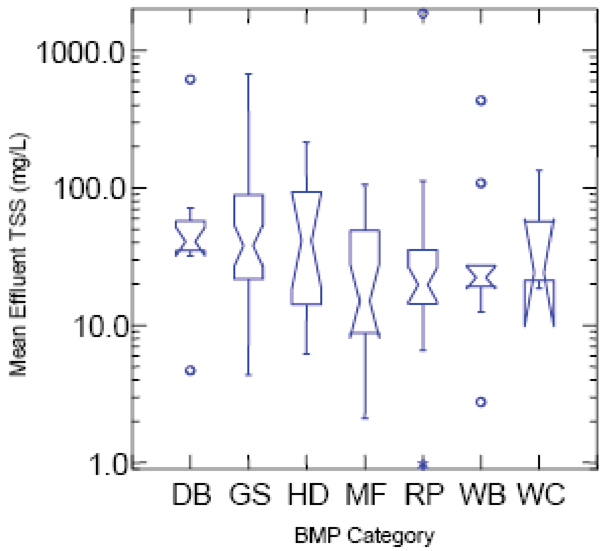



Figure 1. Mean effluent TSS concentration by BMP category

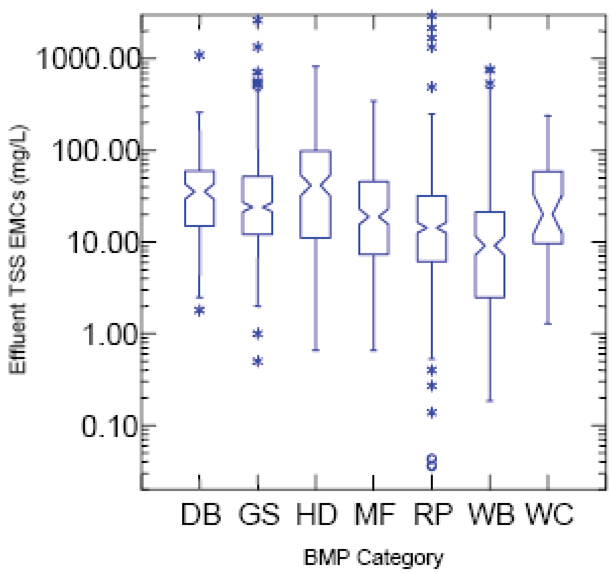



Figure 2. Individual effluent TSS EMCs by BMP category

| | BMP Category | Number of BMPs | Median of Avg. Effluent (95% Confidence Interval)[1] Median | LCL | UCL | Significant Difference Between Average Influent and Effluent[2] | Median of Effluent EMCs (95% Confidence Interval)[1] Median | LCL | UCL | Significant Difference Between Influent and Effluent EMCs[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| DB | Detention Basin | 11 | 40.72 | 32.11 | 51.64 | YES | 32.98 | 26.84 | 40.54 | YES |
| GS | Biofilter | 40 | 37.99 | 26.71 | 54.03 | YES | 24 | 21.34 | 26.99 | NO |
| HD | Hydrodynamic Device | 14 | 41.38 | 18.65 | 91.82 | NO | 36 | 27.58 | 46.99 | YES |
| MF | Media Filter | 19 | 15.05 | 8.09 | 28.02 | YES | 14.97 | 12.23 | 18.31 | YES |
| RP | Retention Pond | 24 | 19.77 | 14.74 | 26.51 | YES | 12 | 10.46 | 13.76 | YES |
| WB | Wetland Basin | 9 | 22.29 | 18.51 | 26.85 | NO | 7.55 | 5.93 | 9.6 | YES |
| WC | Wetland Channel | 3 | 24.18 | 9.83 | 59.45 | YES | 17 | 10.16 | 28.45 | YES |

1. Calculation of confidence interval based on McGill et al (1978), from the natural log of the quantiles.
2. Based on non-parametric analysis of difference in median values.

Analysis of Treatment System Performance    Solids

**Total Dissolved Solids  mg/L**

Total dissolved solids (TDS) is a gross index for solids less than approximately 1 micron. The effectiveness of standard BMP technologies in treating TDS is limited, based on those studies available in the International Stormwater BMP Database.

*Analysis of Mean Effluent TDS Concentration by BMP Category  (one value per BMP Study)*

No significant difference between average influent and effluent TDS concentrations are exhibited for those BMP categories with sufficient number of individual sites to permit useful analysis.

*Analysis of Effluent TDS Concentrations  by BMP Category  (all individual EMCs included in dataset)*

A significant increase between influent and effluent TDS EMCs is exhibited for biofilters, media filters and retention ponds. The remaining categories exhibit no significant difference between median influent and effluent EMCs.

**SEE INTRODUCTION FOR INTERPRETATION OF THESE FIGURES**

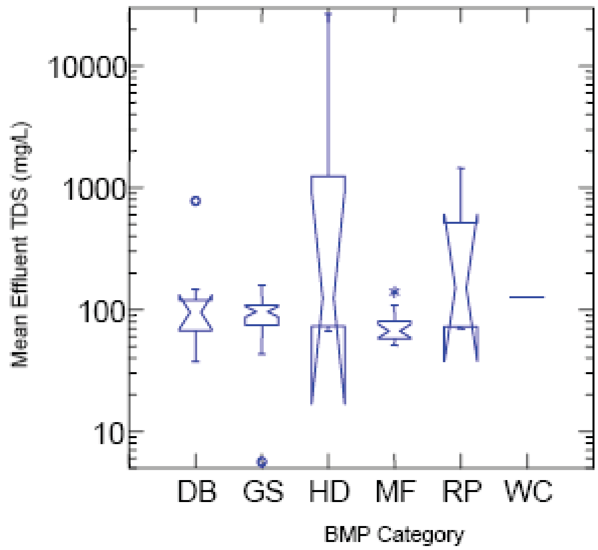



Figure 1. Mean effluent TDS concentration by BMP category

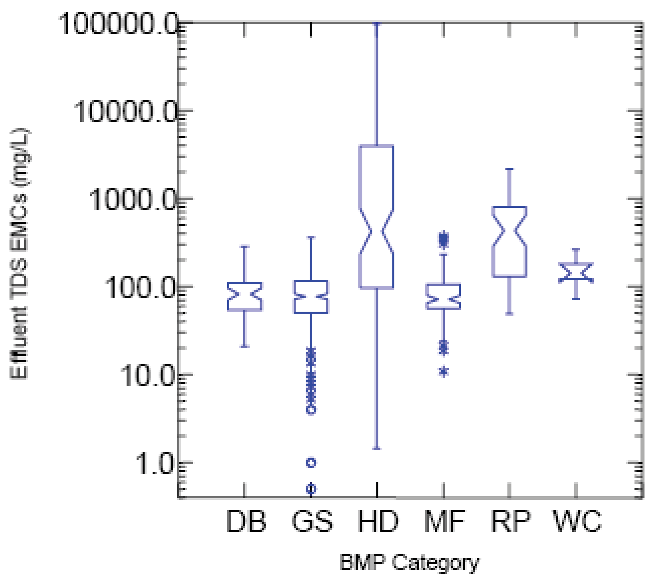



Figure 2. Individual effluent TDS EMCs by BMP category

| | BMP Category | Number of BMPs | Median of Avg. Effluent (95% Confidence Interval)[1] | | | Significant Difference Between Average Influent and Effluent[2] | Median of Effluent EMCs (95% Confidence Interval)[1] | | | Significant Difference Between Influent and Effluent EMCs[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Median | LCL | UCL | | Median | LCL | UCL | |
| DB | Detention Basin | 8 | 64.39 | 33.07 | 125.39 | NO | 82 | 69.83 | 96.29 | NO |
| GS | Biofilter | 36 | 55.56 | 37.23 | 82.91 | NO | 77 | 71.67 | 82.72 | YES[3] |
| HD | Hydrodynamic Device | 5 | 63.75 | 9.3 | 437.24 | NO | 350.93 | 191.55 | 642.92 | NO |
| MF | Media Filter | 16 | 55.76 | 50.32 | 61.78 | NO | 56 | 50.59 | 61.99 | YES[3] |
| RP | Retention Pond | 5 | 142.31 | 36.65 | 552.62 | NO | 359.09 | 235.57 | 547.39 | YES[3] |
| WC | Wetland Channel | 1 | Insufficient sample size for analysis. | | | | 113.98 | 95.07 | 136.66 | NO |

1. Calculation of confidence interval based on McGill et al (1976), from the natural log of the quantiles.
2. Based on non-parametric analysis of difference in median values.
3. Indicates that effluent is significantly greater than influent.

Analysis of Treatment System Performance    Solids