Appendix F:
Sample Calculations

EXAMPLE STORMWATER MANAGEMENT DESIGN CALCULATIONS

A = 20.10 acre site, Weighted "C" = 0.50, Q_{all} = 0.15 cfs/acre

Required Water Quality Volume

= V_{wq} = 1"/12"(43,560)(C)(A)

V_{wq} = 3,630(0.50)(20.10) = 36,482 C.F.

Required Channel Protection Volume

= V_{cp} = 1.3"/12"(43,560)(C)(A)

V_{cp} = 4,719(0.50)(20.10) = 47,426 C.F.

To be stored and infiltrated below outlet elevation.

Required Forebay Volume

= V_{wq} When Detention Basin Infiltration is Proposed (or 15% of V_{wq} With Upstream Infiltration or if Infiltration is not feasible)

= 36,482 C.F. Forebay Volume to be discharged to detention basin at same rate as the Extended Detention Volume is discharged from the basin

Required Extended Detention Volume (For Channel Protection Rate Control)

= V_{ed} = 1.9"/12(43,560)(C)(A)

V_{ed} = 6,897(0.50)((20.10) = 69,315 C.F.

To be discharged over 48 hours

Extended Detention Volume Discharge Rate

= Q_{ed} = V_{ed} /(48 hr)(60 min)(60 sec)

69,315/172,800 = 0.40 cfs

To be used for both Forebay & Detention Basin Outlet Control Design

Required Water Quality Treatment Rate

= Q_{wq} = (C)(A)(97/Tc+30)

Q_{wq} = (0.50)(20.10)(97/21.0+30)

Q_{wq} = 19.11 cfs

Note: T_c = 21.0 min From Storm Sewer Design

1 Yr. Storm Treatment Rate Requirement if a mechanical treatment device is used instead of a forebay for water quality purposes.

100 Yr. Storm Inlet Rate

= $Q_{100in} = (C)(A)(83.30/ (T_c+9.17)^{0.81})$

$Q_{100in} = (0.50)(20.10)(83.30/(21.0+9.17)^{0.81})$

$Q_{100in} = 53.01$ cfs

Note: $T_c = 21.0$ min From Storm Sewer Design

100 Yr. Storm Allowable Outlet Rate

= Q_{100all} = Lesser of Restricted Rate for Drain or Variable Release Rate (Q_{vrr})

$Q_{100all} = 0.15$ cfs/acre x 20.10 acres = 3.02 cfs

Variable Release Rate (When Applicable)

= $Q_{vrr} = 1.1055 – 0.206$ LN (A)

$Q_{vrr} = 1.1055 – 0.206$ LN (20.10)

$Q_{vrr} = 0.487$ cfs/acre

Required 100 Yr. Storm Detention Volume

Storage Curve Factor

= $R = 0.206 – (0.15)(LN(Q_{all}/Q_{100in}))$

$R = 0.206 – (0.15)(LN(3.02/53.01))$

$R = 0.636$

100 Yr. Storm Volume In

= $V_{100in} = 18{,}985(C)(A)$

$V_{100in} = 190{,}799$ C.F.

Required 100 Yr. Storm Storage Volume Above Outlet

= $V_{100det} = (V_{100in})(R) – V_{cp}$ Credit

= 190,799(0.636) – 47,426

= 121,348 – 47,426 = 73,922 C.F.

Since 73,922 c.f. Is More Than the Required Extended Detention Volume of 69,315 C.F., the Minimum Required 100 Yr. Storm Storage Volume Is the 100 Year Storm Storage Volume of 73,922 C.F.

Design Calculations For Infiltration of Channel Protection Volume

For Sandy Loam (Type B) Soils with a 1”/hr In-Situ Infiltration Rate:

Max. Total Water Storage Depth = 1.0”/hr x 72 hr = 72” or 6 ft.
Max. Surface Water Storage Depth = 1.0”/hr x 24 hr = 24” or 2 ft.
Infiltration Depth During Storm = 1.0”/hr x 6 hr = 6” or 0.5 ft.
Potential Soil Storage Depth = 1.0”/hr x 48 hr = 48” or 4 ft.
Potential Soil Storage Depth EQV = 48”x0.25 porosity = 12” or 1 ft.

- Since the potential soil storage is relatively expensive & the soils are reasonably permeable, the most economical storage to meet the infiltration requirement will still be surface water storage located in the bottom of the detention basin.

The Detention Basin Bottom Infiltration Area Required
(Below the basin outlet elevation)
= 47,426 C.F./ (2 ft. Surface + 0.5 ft. Infiltration) Depth
= 18,970 S.F. Required

For Loamy (Type C) Soils with a 0.50”/hr In-Situ Infiltration Rate:

Max. Total Water Storage Depth = 0.50”/hr x 72 hr = 36” or 3.0 ft.
Max. Surface Water Storage Depth = 0.5”/hr x 24 hr = 12” or 1.0 ft.
Infiltration Depth During Storm = 0.5”/hr x 6 hr = 3” or 0.25 ft.
Potential Soil Storage Depth = 0.5”/hr x 48 hr = 24” or 2.0 ft.
Potential Soil Storage Depth EQV = 24”x0.25 porosity = 6” or 0.5 ft.

- Since the soil permeability is relatively low, a combination of surface water storage & soil storage will be utilized in the bottom of the detention basin to meet the infiltration requirement.

The Detention Basin Bottom Infiltration Area Required
(Below the basin outlet elevation)
= 47,426 C.F./ (1 ft. Surface + 0.25 ft. Infiltration + 0.5 ft. Soil) Depth
= 27,101 S.F. Required

Design Calculations for Required Storage & Outlet Orifice With 1"/hr Infiltration Rate

Storage Volumes Required For Infiltration Within Basin Bottom Area

- In Forebay Above Outlet Elevation = 100% V_{wq} = 36,482 C.F.
- In Detention Basin Below Outlet Elevation 2.0/2.5xV_{cp} = 37,941 C.F.
  With 2 Foot Maximum Depth & 18,970 S.F. Avg. Bottom Area
- In Combined Detention Basin & Forebay (Above Outlet)
  = V_{ed} of 69,315 C.F. & V_{100det} of 73,922 C.F.

Storage Volume Provided In Forebay

Contour	Area (Sq. Ft.)	Avg. Area (Sq. Ft.)	Incr. Depth (Ft.)	Incremental Volume (C.F.)	Cumulative Volume (C.F.)
850.0 (L.W.)	12,100	0	0	0	0
851.0	14,400	13,250	1.0	13,250	13,250
852.0	16,900	15,650	1.0	15,650	28,900
852.5 (H.W.)	18,225	17,563	0.5	8,782	37,682

Storage Volume Provided In Detention Basin

Contour	Area (Sq. Ft.)	Avg. Area (Sq. Ft.)	Incr. Depth (Ft.)	Incremental Volume (C.F.)	Cumulative Volume (C.F.)	Cumulative Volume Incl. Forebay (C.F.)
848.0 (Bot.)	16,500	0	0	0	0	0
849.0	19,250	17,875	1.0	17,875	17,875	0
850.0 (L.W.)	22,200	17,725	1.0	20,725	38,600	0
851.0	25,350	23,775	1.0	23,775	23,775	61,457
852.0 (H.W.)	28,700	27,025	1.0	27,025	50,800	88,482
853.0 (F.B.)	54,750	41,725	1.0	41,725	92,525	130,207

Required Forebay 100% V_{wq} Storage Elevation (Above Outlet)
= (0.5(36,482-28,900)/8,782) + 852.0 = 852.43
Required Detention Basin Sump 80% V_{cp} Storage Elevation
= (1.0(37,941-17,875)/20,725) + 849.0 = 849.97
Required Detention Basin Storage Elevations (Above Outlet)
For V_{ed} = (1.0(69,315-61,457)/27,025) + 851.0 = 851.29
For V_{100det} = (1.0(73,922-61,457)/27,025) + 851.0 = 851.46

Extended Detention Orifice Design

Orifice Area = $Q_{ed}/0.62\sqrt{2(g)(h)}$
Orifice Area = $0.40/0.62\sqrt{2(32.2)(0.65)}$
Orifice Area = 0.09972 S.F.

Number of 1" Dia. Holes Required
= 0.09972/0.00545 = 18.30 Holes

Where: Q_{ed} = Discharge Rate
Q_{ed} = 0.40 CFS
g = 32.2 Ft/Sec^2
h = Avg. Hyd. Head
h = 0.5 (851.29-850.00)
h = 0.65 Ft.

Use 18 – 1" Dia. Orifice Holes At El. 850.00
On Both Forebay & Detention Basin Outlet Control Structures
(Forebay OCS Rim El. 852.50 & Detention Basin OCS Rim El. 852.00)

100 Year Storm Orifice Design

Flow Through Extended Detention Orifices With Full Hydraulic Head:
Q_{ED} = $18(0.00545)0.62\sqrt{2(g)(h)}$
Q_{ED} = $18(0.00545)0.62\sqrt{2(32.2)(1.46)}$
Q_{ED} = 0.59 CFS

Where: h = Full Hyd. Head
h = 851.46-850.00
h = 1.46 Ft.

Flow Through 100 Year Storm Orifices:
$Q_{100YR} = Q_{100all} - Q_{ed}$
Q_{100YR} = 3.02-0.59 = 2.43 CFS

Orifice Area = $Q_{100YR}/0.62\sqrt{2(g)(h)}$
Orifice Area = $2.43/0.62\sqrt{2(32.2)(0.17)}$
Orifice Area = 1.18453 S.F.

Where: h = Full Hyd. Head
h = 851.46-851.29
h = 0.17 Ft.

Number of 3" Dia. Holes Required
= 1.18453/0.04909 = 24.13 Holes

Use 24 – 3" Dia. Orifice Holes At El. 851.29
On The Detention Basin Outlet Control Structure
(Detention Basin OCS Rim El. 852.00)

Design Calculations For Required Storage & Outlet Design With 0.5”/hr Infiltration Rate

Storage Volumes Required For Infiltration Within Basin Bottom Area

- In Forebay Above Outlet Elevation = 100% V_{wq} = 36,482 C.F.
- In Detention Basin Below Outlet Elevation 1.0/1.75xV_{cp} = 27,101 C.F.
  With 1 Foot Maximum Depth & 27,101 S.F. Avg. Bottom Area
- In Combined Detention Basin & Forebay (Above Outlet)
  = V_{ed} of 69,315 C.F. & V_{100det} of 73,992 C.F.

Storage Volume Provided In Forebay

Contour	Area (Sq. Ft.)	Avg. Area (Sq. Ft.)	Incr. Depth (Ft.)	Incremental Volume (C.F.)	Cumulative Volume (C.F.)
850.0 (L.W.)	12,100	0	0	0	0
851.0	14,400	13,250	1.0	13,250	13,250
852.0	16,900	15,650	1.0	15,650	28,900
852.5 (H.W.)	18,225	17,563	0.5	8,782	37,682

Storage Volume Provided In Detention Basin

Contour	Area (Sq. Ft.)	Avg. Area (Sq. Ft.)	Incr. Depth (Ft.)	Incremental Volume (C.F.)	Cumulative Volume (C.F.)	Cumulative Volume Incl. Forebay (C.F.)
849.0 (Bot.)	25,850	0	0	0	0	0
850.0 (L.W.)	29,400	27,625	1.0	27,625	27,625	0
851.0	33,150	31,275	1.0	31,275	31,275	68,957
852.0 (H.W.)	37,100	35,125	1.0	35,125	66,400	104,082
853.0 (F.B.)	63,750	50,425	1.0	50,425	116,825	154,507

Required Forebay 100% V_{wq} Storage Elevation (Above Outlet)
= (0.5(36,482-28,900)/8,782) + 852.0 = 852.43
Required Detention Basin Sump 57.14% V_{cp} Storage Elevation
= (1.0(27,101/27,625) + 849.0 = 849.98
Required Detention Basin Storage Elevations (Above Outlet)
For V_{ed} = (1.0(69,315-68,957)/35,125) + 851.0 = 851.01
For V_{100det} = (1.0(73,922-68,957)/35,125) + 851.0 = 851.14

Extended Detention Orifice Design

Orifice Area = $Q_{ed}/0.62\sqrt{2(g)(h)}$
Orifice Area = $0.40/0.62\sqrt{2(32.2)(0.51)}$
Orifice Area = 0.11257 S.F.

Number of 1" Dia. Holes Required
= 0.11257/0.00545 = 20.65 Holes

Where: Q_{ed} = Discharge Rate
Q_{ed} = 0.40 CFS
g = 32.2 Ft/Sec^2
h = Avg. Hyd. Head
h = 0.5 (851.01-850.00)
h = 0.51 Ft.

Use 20 – 1" Dia. Orifice Holes At El. 850.00
On Both Forebay & Detention Basin Outlet Control Structures
(Forebay OCS Rim El. 852.50 & Detention Basin OCS Rim El. 852.00)

100 Year Storm Orifice Design

Flow Through Extended Detention Orifices With Full Hydraulic Head:
Q_{ED} = $20(0.00545)0.62\sqrt{2(g)(h)}$
Q_{ED} = $20(0.00545)0.62\sqrt{2(32.2)(1.14)}$
Q_{ED} = 0.58 CFS

Where: h = Full Hyd. Head
h = 851.14-850.00
h = 1.14 Ft.

Flow Through 100 Year Storm Orifices:
$Q_{100YR} = Q_{100all} - Q_{ed}$
Q_{100YR} = 3.02-0.58 = 2.44 CFS

Orifice Area = $Q_{100YR}/0.62\sqrt{2(32.2)(h)}$
Orifice Area = $2.44/0.62\sqrt{2(32.2)(0.13)}$
Orifice Area = 1.36014 S.F.

Where: h = Full Hyd. Head
h = 851.14-851.01
h = 0.13 Ft.

Number of 3" Dia. Holes Required
= 1.36014/0.04909 = 27.71 Holes

Use 27 – 3" Dia. Orifice Holes At El. 851.01
On The Detention Basin Outlet Control Structure
(Detention Basin OCS Rim El. 852.00)

Design Calculations For Required Storage & Outlet When Infiltration Is Not Feasible

Storage Volumes Required

- In Forebay Above Outlet Elevation = 15% V_{wq} = 5,472 C.F.
- In Combined Detention Basin & Forebay (Above Outlet)
  = V_{ed} of 69,315 C.F. & V_{100det} of 121,348 C.F.

Storage Volume Provided In Forebay

Contour	Area (Sq. Ft.)	Avg. Area (Sq. Ft.)	Incr. Depth (Ft.)	Incremental Volume (C.F.)	Cumulative Volume (C.F.)
850.0 (L.W.)	1,600	0	0	0	0
851.0	2,500	2,050	1.0	2,050	2,050
852.0	3,600	3,050	1.0	3,050	5,100
852.5 (H.W.)	4,225	3,913	0.5	1,957	7,057
853.0	4,900	4,563	0.5	2,119	9,176

Storage Volume Provided In Detention Basin

Contour	Area (Sq. Ft.)	Avg. Area (Sq. Ft.)	Incr. Depth (Ft.)	Incremental Volume (C.F.)	Cumulative Volume (C.F.)	Cumulative Volume Incl. Forebay (C.F.)
850.0 (L.W.)	17,200	0	0	0	0	0
851.0	22,000	19,600	1.0	19,600	19,600	28,776
852.0	27,000	24,500	1.0	24,500	44,100	53,276
853.0	32,200	29,600	1.0	29,600	73,700	82,876
853.0	37,100	34,650	0	0	73,700	82,876
854.0 (H.W.)	44,000	40,550	1.0	40,550	114,250	123,426
855.0 (F.B.)	50,400	47,200	1.0	47,200	161,450	170,626

Required Forebay 15% V_{wq} Storage Elevation (Above Outlet)
= (0.5(5,472-5,100)/1,957) + 852.0 = 852.10
Required Detention Basin Storage Elevations (Above Outlet)
For V_{ed} = (1.0(69,315-53,276)/29,600) + 852.0 = 852.54
For V_{100det} = (1.0(121,348-82,876)/40,550) + 853.0 = 853.95

Extended Detention Orifice Design

Orifice Area = $Q_{ed}/0.62\sqrt{2(g)(h)}$
Orifice Area = $0.40/0.62\sqrt{2(32.2)(1.27)}$
Orifice Area = 0.07134 S.F.

Number of 1" Dia. Holes Required
= 0.07134/0.00545 = 13.09 Holes

Where: Q_{ed} = Discharge Rate
Q_{ed} = 0.40 CFS
g = 32.2 Ft/Sec^2
h = Avg. Hyd. Head
h = 0.5 (852.54-850.00)
h = 1.27 Ft.

Use 13 – 1" Dia. Orifice Holes At El. 850.00
On Both Forebay & Detention Basin Outlet Control Structures
(Forebay OCS Rim El. 852.50 & Detention Basin OCS Rim El. 854.00)

100 Year Storm Orifice Design

Flow Through Extended Detention Orifices With Full Hydraulic Head:
Q_{ED} = $13(0.00545)0.62\sqrt{2(g)(h)}$
Q_{ED} = $13(0.00545)0.62\sqrt{2(32.2)(3.95)}$
Q_{ED} = 0.70 CFS

Where: h = Full Hyd. Head
h = 853.95-850.00
h = 3.95 Ft.

Flow Through 100 Year Storm Orifices:
$Q_{100YR} = Q_{100all} - Q_{ed}$
Q_{100YR} = 3.02-0.70 = 2.32 CFS

Orifice Area = $Q_{100YR}/0.62\sqrt{2(g)(h)}$
Orifice Area = $2.32/0.62\sqrt{2(32.2)(1.41)}$
Orifice Area = 0.39268 S.F.

Where: h = Full Hyd. Head
h = 853.95-852.54
h = 1.41 Ft.

Number of 3" Dia. Holes Required
= 0.39268/0.04909 = 8.00 Holes

Use 8 – 3" Dia. Orifice Holes At El. 852.54
On The Detention Basin Outlet Control Structure
(Detention Basin OCS Rim El. 854.00)