New York City Stormwater Manual

Appendix E
SITE DESIGN EXAMPLE

Environmental Protection

Site Design Example

Design stormwater management practices for a 21,545 square foot commercial development that proposes a new site connection. This site is located within the sewershed of a combined sewer system and has no site constraints. Based on geotechnical investigations, the soil permeability rate across the site is at least 0.5 in/hr.

Step 1: Determine applicable permit requirements for the site.

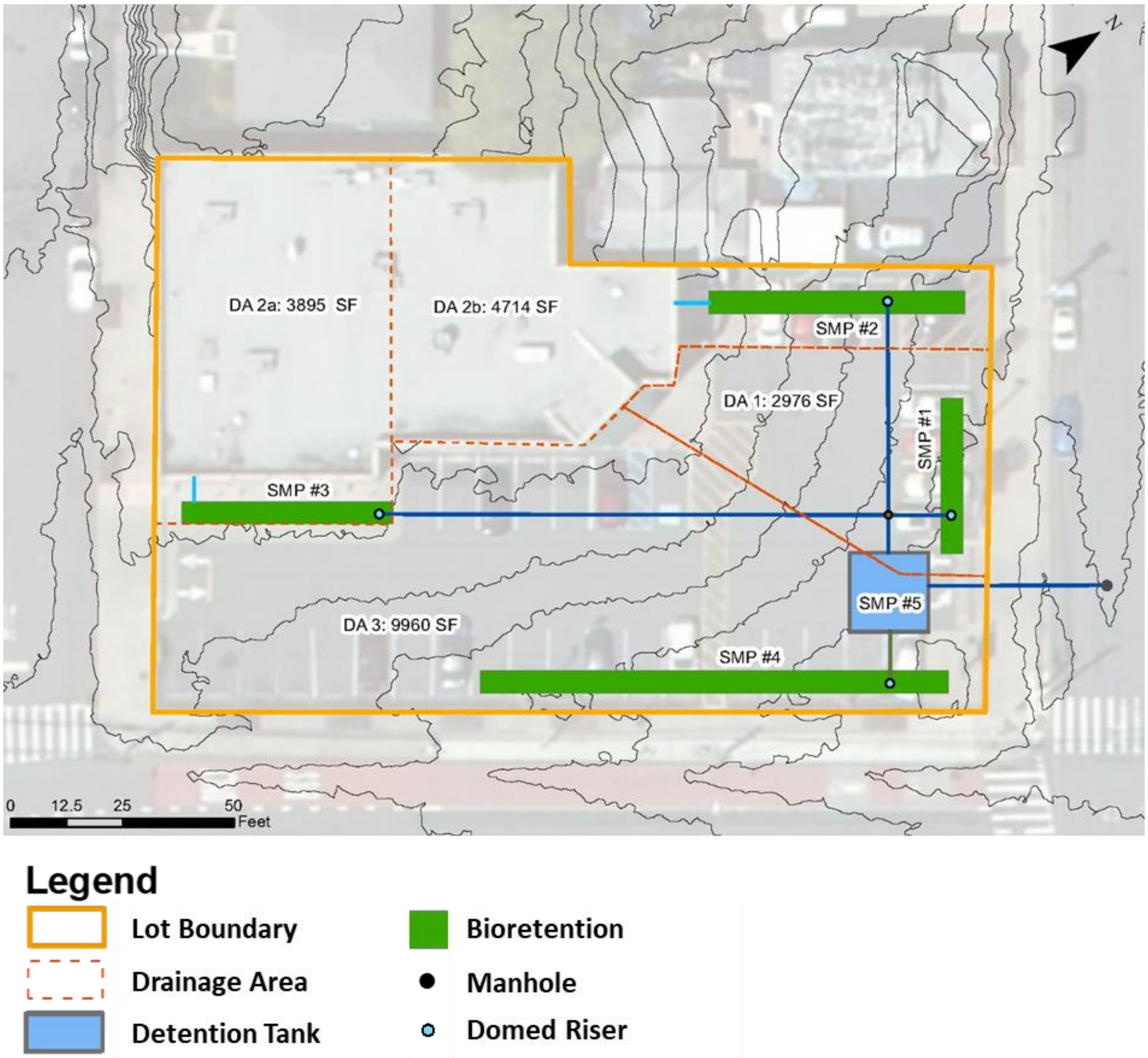
Since the project disturbs more than 20,000 square feet and involves commercial development, a Stormwater Construction Permit is applicable. As shown in Table 2.3 of Chapter 2, commercial development is a covered development activity that requires the preparation of a SWPPP meeting erosion and sediment control (ESC), water quality (WQ_V), and runoff reduction (RR) requirements. The no-net increase (NNI) requirement is not applicable because the project is not located in an MS4 sewershed area and does not discharge into an impaired water body.

The project proposes a new site connection and is located within the sewershed of a combined sewer system. Therefore, a Site Connection Permit is also applicable. A connection proposal must be prepared to meet the sewer operations (V_V) requirements.

Step 2: Use Appendix C to select appropriate practices for meeting the WQ_V, RR, and V_V requirements. The ESC requirements should be met using best practices in accordance with the NYS Standards and Specifications for Erosion and Sediment Control (The Blue Book).

Since the site has no constraints and the soil permeability rate is at least 0.5 in/hr, an infiltration practice is preferred. To meet the WQ_V and RR requirements, the designer has chosen to use a bioretention practice for each of the four drainage areas. The designer has chosen to use a detention tank to meet the V_V requirements.

Figure G.1. Schematic of Scenario 1



SMP 1: Bioretention

Design a bioretention practice (SMP 1) that will treat the water quality volume from an impervious area of 2,976 square feet with a runoff coefficient of 0.95. This example assumes a soil media saturated hydraulic conductivity of 2 in/hr, and an infiltration rate of 1.5 in/hr.

Note: If a bioretention practice is designed to meet the water quality volume, the practice will, by default, also meet the runoff reduction criteria.

Step 3.1: Calculate the WQ_V.

$$WQ_V = \frac{1.5\ in}{12} * A * \ R_V$$

where:

WQ_V = water quality volume (cf)

A = contributing area (sf) = 2,976 sf

R_V = runoff coefficient relating total rainfall and runoff

R_V = 0.05 + 0.009(I) = 0.95

I = percent impervious cover = 100%

$$WQ_V = \frac{1.5\ in}{12} * 2{,}976\ sf * \ 0.95$$

$$WQ_V = 353.4\ cf$$

Step 3.2: Calculate the minimum SMP area using the maximum loading ratio of 1:20 for a bioretention practice. Use the minimum area to set the initial length and width of the practice.

$$A_{SMP} = \frac{A}{20}$$

where:

A_{SMP} = area at the base of infiltration SMP (sf)

A = contributing area (sf) = 2,976 sf

$$A_{SMP} = \frac{2{,}976\ sf}{20}$$

$$A_{SMP} = 148.8\ sf$$

Round the SMP area up to 150 sf. Assume a 30 ft by 5 ft practice.

Step 3.3: Calculate the volume of surface ponding assuming the maximum surface ponding depth of 1 ft for a bioretention practice.

Assume the ponding zone is relatively flat.

$$V_P = A_{SMP} * D_P$$

where:
V_P = volume of surface ponding (cf)
A_{SMP} = area of the SMP (sf) = 150 sf
D_P = depth of ponding (ft) = 1 ft

$$V_P = 150\ sf * 1\ ft$$

$$V_P = 150\ cf$$

Since the bioretention practice uses engineered soil media, confirm that the volume of surface ponding is at least 10% of the water quality volume.

$$V_P = 150\ cf > 10\%\ of\ WQ_V = 35.3\ cf \qquad OK$$

In this case, the designer has also chosen to use a hydraulic connection between the ponding zone and the stone base. Therefore, the ponding zone does not need to temporarily store 75% of the water quality volume.

Step 3.4: Calculate the volume of voids in the soil media layer assuming a soil media depth of 2.5 ft, equal to the minimum soil media depth of 2.5 ft for a bioretention practice.

$$V_S = A_{SMP} * D_S * n_S$$

V_S = volume of voids in the soil media layer (cf)
A_{SMP} = area of the SMP (sf) = 150 sf
D_S = depth of soil media layer (ft) = 2.5 ft
n_S = available porosity of soil media (cf/cf) = 0.2 cf/cf

$$V_S = 150\ sf * 2.5\ ft\ * 0.2 \frac{cf}{cf}$$

$$V_S = 75\ cf$$

Step 3.5: Calculate the volume of voids created by internal structures.

Assume there are no internal structures in this bioretention practice, so the volume is 0.

$$V_I = 0\ cf$$

Step 3.6: Calculate the volume of voids in the drainage layer assuming a drainage media depth of 2.5 ft, which is greater than the minimum drainage media depth of 1 ft for a bioretention practice.

$$V_D = (A_{SMP} * D_D - V_{I,d}) * n_D$$

where:
V_D = volume of voids in the drainage layer (cf)
A_{SMP} = area of the SMP (sf) = 150 cf
D_D = depth of the drainage layer (ft) = 2.5 ft
$V_{I,d}$ = volume of voids created by internal structures within the drainage layer (cf) = 0 cf
n_D = porosity of drainage layer media (cf/cf) = 0.4 cf/cf

$$V_D = (150\ sf * 2.5\ ft - 0\ cf) * 0.4 \frac{cf}{cf}$$

$$V_D = 150\ cf$$

Step 3.7: Calculate the total SMP volume from the individual component volumes and compare to the WQ_V.

$$V_{SMP} = V_P + V_S + V_I + V_D$$

where:
V_{SMP} = storage volume of SMP (cf)
V_P = volume of surface ponding (cf) = 150 cf
V_S = volume of voids in the soil media layer (cf) = 75 cf
V_I = volume of voids created by internal structures such as chambers or pipes (cf) = 0 cf
V_D = volume of voids in the drainage layer (cf) = 150 cf

$$V_{SMP} = 150\ cf + 75\ cf + 0\ cf + 150\ cf$$

$$V_{SMP} = 375\ cf > WQ_V = 353.4\ cf \qquad OK$$

Step 3.8: Check that the ponding and infiltration drawdown times of the practice do not exceed the required times of 24 hours and 48 hours, respectively.

Infiltration drawdown time:

$$dt_{SMP} = \frac{V_{SMP}}{\left(\frac{i}{12}\right) * A_{SMP}}$$

where:

dt_{SMP} = drawdown time of infiltration SMP (hr)

V_{SMP} = volume of infiltration SMP (cf) = WQ_V = 375 cf

i = field measured infiltration rate (in/hr) = 1.5 in/hr

A_{SMP} = area at the base of infiltration SMP (sf) = 150 sf

$$dt_{SMP} = \frac{375\ cf}{\left(\frac{1.5\ in/hr}{12}\right) * 150\ sf}$$

$$dt_{SMP} = 20\ hr < 48\ hr \qquad OK$$

Surface ponding drawdown time:

$$dt_P = \frac{V_P}{\left(\frac{K_S}{12}\right) * \left(1 + \frac{0.5 D_p}{D_m}\right) * \left(\frac{A_{P1} + A_{P2}}{2}\right)}$$

where:

dt_P = drawdown time of surface ponding (hr)

V_P = volume of surface ponding (cf) = 150 cf

K_S = saturated hydraulic conductivity of media below the surface ponding area (in/hr) = 2 in/hr

D_p = maximum depth of ponding (ft) = 1 ft

D_m = depth of media below surface ponding area (ft) = 2.5 ft

A_{P1} = area at the base of surface ponding zone (sf) = 150 sf

A_{P2} = area at the top of surface ponding zone (sf) = 150 sf

$$dt_P = \frac{150\ cf}{\left(\frac{2\frac{in}{hr}}{12}\right) * \left(1 + \frac{0.5 * 1\ ft}{2.5\ ft}\right) * \left(\frac{150\ sf + 150\ sf}{2}\right)}$$

$$dt_P = 5\ hr < 24\ hr \qquad OK$$

SMP 2-4: Bioretention

Steps 4-6: Design bioretention practices (SMP 2, SMP 3, and SMP 4) for the other three drainage areas by running through the same steps as for SMP 1. Assume a soil media saturated hydraulic conductivity of 2 in/hr, and an infiltration rate of 1.5 in/hr.

Table G.1 shows the final dimensions, SMP volume, and required water quality volume for each bioretention practice.

Table G.1. Summary of WQ_V Design

SMP #	Drainage Area (sf)	Dimensions (L' x W' x D')	SMP Volume (cf)	WQ_V (cf)
1	2,976	30 x 5 x 6	375	353.4
2	4,714	48 x 5 x 6	600	559.8
3	3,895	39 x 5 x 6	487.5	462.5
4	9,960	100 x 5 x 6	1,250	1,182.8

SMP 5: Detention Tank

Design a detention tank (SMP 5) that will treat the sewer operations volume from an impervious area of 21,545 square feet with a weighted runoff coefficient of 0.88.

Step 7.1: Identify the rainfall depth (R_D) based on the sewershed type and connection proposal type for the project. Use Table 2.7 in Chapter 2.

As determined in Step 1, the project requires a site connection permit (SCP). In addition, the project is located within the sewershed of a combined sewer system.

Table 2.7. Applied rainfall depth by sewershed type and connection proposal type.

R_D	Description
1.85	CSS areas with SCP
1.50	CSS areas with HCP
1.50	MS4 areas wiith SCP
1.10	MS4 areas with HCP

According to Table 2.7, $R_D = 1.85\ in.$

Step 7.2: Calculate the total V_V.

$$V_V = \frac{R_D}{12} * A * C_W$$

where:

V_V = sewer operations volume (cf)

R_D = rainfall depth (in) = 1.85 in

A = contributing area (sf) = 21,545 sf

C_W = weighted runoff coefficient relating peak rate of rainfall and runoff = 0.88

$$V_V = \frac{1.85\ in}{12} * 21{,}545\ sf * 0.88$$

$$V_V = 2{,}922.9\ cf$$

Step 7.3: Subtract the amount of SMP volume that may be credited towards meeting the total V_V from Step 7.2. The remaining volume ($V_{V,Tank}$) must be managed by the detention tank.

50% of the V_{SMP} from each bioretention practice can be credited towards the V_V.

Total creditable V_{SMP}:

$$V_{SMP,TC} = 0.5(V_{SMP,1} + V_{SMP,2} + V_{SMP,3} + V_{SMP,4})$$

where:

$V_{SMP,TC}$ = total creditable SMP volume (cf)

$V_{SMP,1}$ = volume from SMP 1 (cf) = 375 cf

$V_{SMP,2}$ = volume from SMP 2 (cf) = 600 cf

$V_{SMP,3}$ = volume from SMP 3 (cf) = 487.5 cf

$V_{SMP,4}$ = volume from SMP 4 (cf) = 1,250 cf

$$V_{SMP,TC} = 0.5(375\ cf + 600\ cf + 487.5\ cf + 1{,}250\ cf)$$

$$V_{SMP,TC} = 1{,}356.25\ cf$$

Remaining volume managed by the detention tank:

$$V_{V,Tank} = 2{,}922.9\ cf - 1{,}356.25\ cf$$

$$V_{V,Tank} = 1{,}566.65\ cf$$

Step 7.4: Calculate the release rate to be maintained by the controlled-flow orifice. Use the maximum release rate per acre (q) shown in Table 2.9, Chapter 2.

The project is located within the sewershed of a combined sewer system.

Table 2.9. Maximum release rate per acre (cfs/acre) by sewershed type.

q (cfs/acre)	Description
1.0	MS4 areas
0.1	CSS areas

According to Table 2.9, $q = 0.1\frac{cfs}{acre}$.

$$Q_{DRR} = \frac{q\ * A}{43560}\ or\ 0.046\ \ [whichever\ is\ greater]$$

where:

Q_{DRR} = maximum release rate for the site (cfs)

q = maximum release rate per acre (cfs/acre) = 0.1 cfs/acre

A = contributing area (sf) = 93,200 sf

$$Q_{DRR} = \frac{0.1\ \frac{cfs}{acre} * 21{,}545\ sf}{43560}\ or\ 0.046\ \ [whichever\ is\ greater]$$

$$Q_{DRR} = 0.049\ cfs\ > 0.046\ cfs$$

The maximum release rate is 0.049 cfs.

Step 7.5: Use the controlled-flow orifice equation to determine an appropriate orifice area by assuming the active storage depth.

In order to minimize the area required for the detention tank, choose the maximum depth that is still feasible according to site limitations and use a re-entrant orifice. In this case, the designer has chosen an active storage depth of 4 ft.

$$Q_O = C_D * A_o * \sqrt{2gH}$$

where:

Q_O = maximum release rate of orifice (cfs) = 0.049 cfs

C_D = coefficient of discharge, 0.52 for re-entrant orifice

A_O = area of orifice (sf)

g = acceleration due to gravity, 32.2 (ft/s^2)

H = maximum hydraulic head above the centerline of the orifice (ft) = 4 ft

$$0.049\ cfs = 0.52 * A_o * \sqrt{2 * 32.2\ \left(\frac{ft}{s^2}\right) * 4\ ft}$$

$$A_o = 0.006\ sf$$

Step 7.6: Translate the area of the controlled-flow orifice (A_O) into a diameter and check that it is greater than the minimum diameter of 1 in.

$$A_o = \frac{\left[\pi * \left(\frac{D_o}{2}\right)^2\right]}{144}$$

where:

A_O = area of orifice (sf) = 0.006 sf

D_O = diameter of orifice (in)

$$0.006\ sf = \frac{\left[\pi * \left(\frac{D_O}{2}\right)^2\right]}{144}$$

$$D_O = 1.05\ in\ > 1\ in \qquad OK$$

Set the orifice diameter to the nearest 0.25-inch interval rounding down, with a minimum orifice diameter of one-inch. In this case, use an orifice diameter of 1.00 inch.

Step 7.7: Confirm the orifice area of the selected orifice diameter from Step 7.6.

$$A_o = \frac{\left[\pi * \left(\frac{D_o}{2}\right)^2\right]}{144}$$

where:

A_O = area of orifice (sf)

D_O = diameter of orifice (in) = 1 in

$$A_O = \frac{\left[\pi * \left(\frac{1\ in}{2}\right)^2\right]}{144}$$

$$A_O = 0.005\ sf$$

Step 7.8: Confirm the required active storage depth in the tank using the orifice area from Step 7.7.

$$Q_O = C_D * A_o * \sqrt{2gH}$$

where:

Q_O = maximum release rate of orifice (cfs) = 0.049 cfs

C_D = coefficient of discharge, 0.52 for re-entrant orifice

A_O = area of orifice (sf) = 0.005 sf

g = acceleration due to gravity, 32.2 (ft/s^2)

H = maximum hydraulic head above the centerline of the orifice (ft)

$$0.049\ cfs = 0.52 * 0.005\ sf * \sqrt{2 * 32.2\ \left(\frac{ft}{s^2}\right) * H}$$

$$H = 5.5\ ft$$

If the active storage depth is too high, then increase the orifice size by 0.25 inches and re-run Steps 7.7-7.8 until a suitable depth is identified. If the active storage depth is too low, then decrease the orifice size by 0.25 inches (but not less than 1 inch) and re-run Steps 7.7-7.8. Alternatively, the designer can choose a different orifice configuration as needed to modify the active storage depth.

In this case, the depth is feasible.

Step 7.9: Set the dimensions of the detention tank's active storage zone.

Based on the active storage depth of 5.5 ft and the $V_{V,Tank}$ of 1,566.65 cf, set the interior detention tank dimensions to L: 17 ft and W: 17 ft. The resulting detention tank has an active storage volume of 1,589.5 cf. Note that the exterior dimensions of the detention tank will be larger than the dimensions of the active storage zone (17'L x 17'W x 5.5'D) to accommodate wall thickness, bypass structures, and/or other internal features.

Table G.2 summarizes the final designs for the bioretention practices and the detention tank.

Table G.2. Summary of WQ_V and V_V Design

SMP #	Drainage Area (sf)	Dimensions (L' x W' x D')	SMP Volume (cf)	WQ_V (cf)	V_V (cf)
1	2,976	30 x 5 x 6	375	353.4	187.5
2	4,714	48 x 5 x 6	600	559.8	300
3	3,895	39 x 5 x 6	487.5	462.5	243.75
4	9,960	100 x 5 x 6	1,250	1,182.8	625
5	21,545	17 x 17 x 5.5	1,589.5	0	1,589.5
Total	**21,545**	**-**	**-**	**2,558.5**	**2,945.75**