Temporary Sediment Basin - Design Guide

This design guide is intended to provide guidance on the purpose, design, selection, installation, and maintenance of a sediment basin when used as a temporary sediment control practice to detain sediment from stormwater runoff prior to discharge from a construction site. This design guide serves as a supplement to the IECA Temporary Sediment Basin Design Standard.

Keywords: sediment basin, sediment control, stormwater management, erosion

1. INTRODUCTION

Temporary sediment basins are a sediment control practice designed to detain sediment from stormwater runoff by providing storage to promote gravitational sedimentation thereby reducing offsite sediment discharge. Adequate detention time and volume is essential for gravitational settling to occur. Stormwater residence time within a temporary sediment basin is dependent on size, geometry, energy dissipation, an effective dewatering system, and use of chemical treatment (1, 2). With appropriate design and detention, research has shown that basins can provide removal of suspended solids, heavy metals, and other organic compound by up to 75% (1, 2). This fact sheet is intended to provide an overview of design and installation criteria for the proper application and use of temporary sediment basins.

2. DESIGN

A temporary sediment basin consists of an inflow structure, settling pond, dewatering system, and auxiliary spillway. Figure 1 provides a diagram with key design elements for a sediment basin.

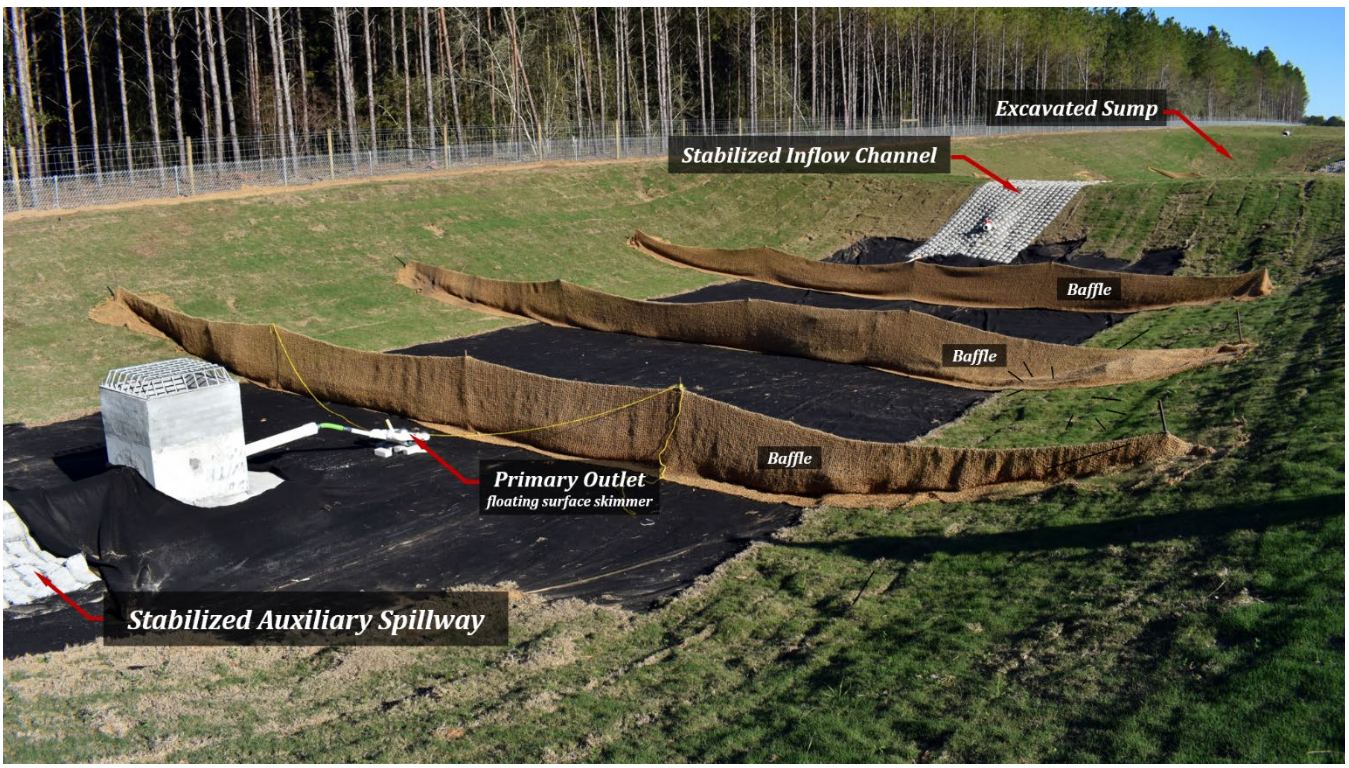

Figure 1. Example sediment basin design elements.

To adequately design temporary sediment control practices used on construction sites, designers must account for local precipitation, frequency, intensity, and duration, as well as expected flows. In addition, soil type and the range of soil particle sizes expected to be present on site should be considered. Designers must furthermore ensure practices are designed and installed in accordance with good engineering practices (3, 4).

2.1 Hydrology and Capacity

A temporary sediment basin provides volume for a standing pool, stormwater storage, auxiliary spillway stage, and freeboard. Figure 2 highlights key dimensions for geometry and sizing.

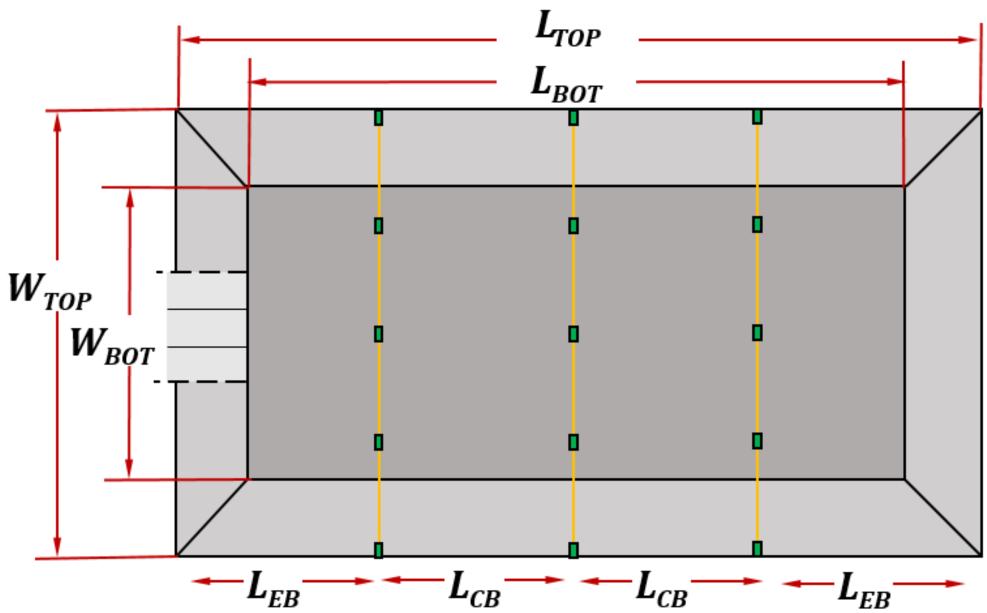

Figure 2. Sediment basin design parameters.

Temporary sediment basins should be designed to detain the selected design storm event. The USEPA allows for the design of sediment basins using the 2-yr, 24-hr design storm volume or providing 250 m³ per ha (3,600 ft³ of storage per ac) drained (5). The design storm sizing approach provides a method to size practices based on site specific conditions. To size a temporary sediment basin based on runoff quantity, the area upstream of the basin should be delineated to determine a design treatment volume for the design storm. The NRCS TR-55 method can be used to determine the treatment volume based on the contributing area, design rainfall depth, and curve number. Curve numbers for soil groups A, B, C, and D in newly graded areas are 77, 86, 91, and 94, respectively. A complete table of curve numbers can be found in NRCS TR-55, Table 2-2 (6).

$$V = \frac{nA\left[P - 0.2\left(\frac{1000}{CN} - 10\right)\right]^2}{12\left[P + 0.8\left(\frac{1000}{CN} - 10\right)\right]} \qquad \text{Eq. 1}$$

where,

- V = runoff volume, m^3 (ft^3)
- n = constant, 1.86 for m^3 (1.0 for ft^3)
- A = area, m^2 (ft^2)
- P = design rainfall depth, cm (in.)
- CN = Curve Number

The inflow channel and auxiliary spillway are required to safely pass the 10-year, 24-hour peak flow rate. Eq. 2 and 3 can be used to determine the peak flow.

$$Q_p = \frac{q_u A(P - I_a)^2}{n^2(P + 4I_a)} \qquad \text{Eq. 2}$$

where,

Q_p = peak flow rate, m³/s (ft³/s)
q_u = unit peak discharge, refer to USDA TR-55
A = contributing drainage area, m² (ft²)
P = 10-yr, 24-hr rainfall depth, cm (in.)
I_a = initial abstraction, cm (in.), Eq. (3)
n = constant, 2,566 for m³/s (5,280 for ft³/s)

$$I_a = 0.2n\left(\frac{1000}{CN} - 10\right) \quad \text{Eq. 3}$$

where,

I_a = initial abstraction, cm (in.)
n = constant, 2.54 for cm (1.0 for in.)
CN = Curve Number

Effectively designing and sizing the standing pool, stormwater storage, auxiliary spillway flow, and freeboard of temporary sediment basins can improve sediment trapping efficiency and reduce the occurrence spillway failures (7, 8).

2.2 Geometry and Placement

Determine site limitations for depth, dam, or auxiliary spillway. Sediment basins should be placed upstream of site discharge points to maximize the detention of sediment-laden stormwater prior to off-site discharge and have an access point for maintenance activities throughout the duration of the project. Once placement is verified, determine the area and shape of the basin, considering a minimum length to width ratio of 2:1 and a total depth of generally no more than 1.5 m (5 ft) (2, 9, 10). The following equations can be used to determine the geometry and volumes for each storage zone of a rectangular basin (4). CAD-based design software may be used to develop non-rectangular sediment basins.

$$W_{TOP} = \frac{L_{TOP}}{L:W} \quad \text{Eq. 4}$$

$$W_{BOT} = W_{TOP} - 2D_{total}(H:V) \quad \text{Eq. 5}$$

$$L_{BOT} = L_{TOP} - 2D_{total}(H:V) \quad \text{Eq. 6}$$

where,

W_{TOP} = top width, m (ft)
L_{Top} = top length, m (ft)
W_{BOT} = bottom width, m (ft)
L_{BOT} = bottom length, m (ft)
D_{total} = total basin depth, m (ft)

Volumes for the standing pool, stormwater storage, spillway and freeboard, and total volume can be calculated using equations 7-10, respectively.:

$$V_{SP} = \frac{D_{SP}}{6}\left[\left(W_{BOT} + 2D_{SP}(H:V)\right)\left(L_{BOT} + 2D_{SP}(H:V)\right) + 4\left(L_{BOT} + D_{SP}(H:V)\right)\left(W_{BOT} + D_{SP}(H:V)\right) + L_{BOT}W_{BOT}\right] \quad \text{Eq. 7}$$

$$V_{SS} = \frac{D_{SS}}{6}\left[\left(W_{BOT} + 2D_{TS}(H:V)\right)\left(L_{BOT} + 2D_{TS}(H:V)\right) + 4\left(L_{BOT} + D_{TS}(H:V) + D_{SP}(H:V)\right)\left(W_{BOT} + D_{TS}(H:V) + D_{SP}(H:V)\right) + (L_{BOT} + 2D_{SP}(H:V))(W_{BOT} + 2D_{SP}(H:V))\right] \quad \text{Eq. 8}$$

$$V_{SW+FB} = \frac{D_{total} - D_{TS}}{6}\left[L_{TOP}W_{TOP} + 4\left(L_{TOP} + D_{TS}(H:V)\right)\left(W_{TOP} + D_{TS}(H:V)\right) + \left(L_{BOT} + 2D_{TS}(H:V)\right)\left(W_{BOT} + 2D_{TS}(H:V)\right)\right] \quad \text{Eq. 9}$$

$$V_{Total} = \frac{D_{total}}{6}\left[L_{TOP}W_{TOP} + (L_{TOP} + L_{BOT})(W_{TOP} + W_{BOT}) + L_{BOT}W_{BOT}\right] \quad \text{Eq. 10}$$

where,

V_{SP} = standing pool volume, m³ (ft³)
V_{SS} = stormwater storage volume, m³ (ft³)
V_{SW+FB} = spillway and freeboard volume, m³ (ft³)
V_{Total} = total volume, m³ (ft³)
W_{TOP} = top width, m (ft)
L_{Top} = top length, m (ft)
W_{BOT} = bottom width, m (ft)
L_{BOT} = bottom length, m (ft)
D_{SP} = standing pool depth, m (ft)
D_{SS} = stormwater storage depth, m (ft)
D_{total} = total basin depth, m (ft)
D_{TS} = total storage ($D_{SP} + D_{SS}$) depth, m (ft)

Sediment basin volumes and depths must comply with local, state, and federal requirements.

2.3 Inflow Channel

The designated inflow channel or conveyance pipe must safely pass the peak flow from the 10-year, 24-hour storm (calculated in Eq.2). If an inflow channel is used, establish vegetative cover or line with non-woven geotextile to ensure that designed flow velocity is non-erosive for channel conditions. Refer to the AASHTO Drainage Manual, Volume 2, Chapter 10 (11) or the FHWA Hydraulic Engineering Circular No. 15 (12) for channel design guidance

2.4 Velocity Dissipation

Baffles should be spaced to create a minimum of four approximately equal volume sections or bays. Eq. 11 can be used to determine the volume per bay.

$$V_{bay} = \frac{V_{TS}}{N_{bay}} \quad \text{Eq. 11}$$

where,

V_{bay} = volume of individual bay, m³ (ft³)
V_{TS} = volume of standing pool and stormwater storage, m³ (ft³)
N_{bay} = desired number of bays

Spacing of the center bays can be calculated using Eq. 12.

$$L_{CB} = \frac{V_{bay}}{\frac{1}{2}(W_{SS} + W_{BOT})d_{SP+SS}} \quad \text{Eq. 12}$$

where,

L_{CB} = length of individual center bay, m (ft)
V_{bay} = volume of individual bay, m³ (ft³)
d_{SP} = depth of standing pool, m (ft)
d_{SS} = depth of stormwater storage, m (ft)
W_{SS} = stormwater storage top width, m (ft)
W_{BOT} = bottom width, m (ft)

Spacing of the first and last bays can be calculated using Eq. 13.

$$L_{EB} = \frac{L_{BOT} - \sum L_{CB}}{2} \quad \text{Eq. 13}$$

where,

L_{EB} = length of end bays, m (ft)
L_{CB} = length of center bays, m (ft)
L_{BOT} = bottom length, m (ft)

2.5 Dewatering

The stormwater storage volume should be dewatered using a surface outlet within 2-5 days. Skimmer outflow rate can be calculated using Eq.14. Manufacturer performance specifications can then be followed to select the skimmer size and orifice diameter.

$$Q = \frac{V}{t_d} \qquad \text{Eq. 14}$$

where,

$Q =$ skimmer outflow rate, m^3/d (ft^3/d)
$V =$ stormwater storage volume, m^3 (ft^3)
$t_d =$ desired dewatering time, days

The dewatering pipe should pass through the dam with at least one anti-seep collar at the center of the dam to prevent water from flowing along the interface between the outlet and the embankment, causing destabilization. Eq.15 can be used to first calculate the length of the dewatering barrel within the saturated zone (13).

$$L_s = Y\,(Z+4)\,\left(1 + \frac{S}{0.25 - S}\right) \qquad \text{Eq. 15}$$

where,

$L_s =$ Length of dewatering barrel within saturated zone (ft)
$Y =$ Depth of water at principal spillway crest (ft)
$Z =$ Slope of upstream face of embankment (H:1V)
$S =$ Slope of the barrel (ft/ft)

Seepage length should be accounted for along the barrel and is considered to be 10% of L_s. The seepage length represents the total collar projection. The collar should be at least 1 m (3 ft) larger than the barrel diameter (0.5 m [1.5 ft] in all directions). Subtract the pipe diameter from the collar size to determine individual collar projection. Determine the number of collars required by dividing the seepage length by the individual collar projection. Collars should be spaced a minimum of 5 times the minimum projection. If space allows, collars should be located within the saturated zone. If space does not allow, at least one collar should be within the saturated zone (14).

2.6 Auxiliary Spillway

The auxiliary spillway should safely pass the peak flow from the 10-year, 24-hour storm (calculated in Eq.2). Considering the spillway as a broad crested weir, the following equation can be used to determine flow depth (4):

$$D_{SW} = \left[\frac{Q_{SW}}{\frac{2}{3}^{3/2} \quad g^{1/2} L_{SW}}\right]^{2/3} \qquad \text{Eq. 16}$$

where,

$D_{SW} =$ spillway flow depth, m (ft)
$Q_{SW} =$ flow rate for spillway design, m^3/s (ft^3/s)
$g =$ gravity, 9.81 m/s^2 (32.2 ft/s^2)
$L_{SW} =$ length of spillway, m (ft)

Ideally, the auxiliary spillway should be positioned in the abutment of the sediment basin dam on undisturbed soil. At this position, the auxiliary spillway should have a straight control and outlet section. The entrance width should be at least 1.5 times wider than the control section width of the spillway. Extend the spillway to an appropriate discharge point to ensure flow is nonerosive. Armor spillway with vegetation or rip rap. Ensure that designed flow velocity is nonerosive for spillway conditions (9). Auxiliary spillways over the top of the embankment should be designed to be stable at the outlet where rock movement generally occurs.

2.7 Erosion Control

Minimize disturbed areas, but stabilize required disturbed areas with permanent vegetation. The basin floor should either (1) establish vegetative cover or (2) be lined with non-woven geotextile to prevent erosion.

2.8 Safety

Provide safety fence and mark with signage. Follow all local and state safety requirements.

2.9 Flocculants

Flocculants may be added upstream of sediment basins (e.g. inlets, ditches, slopes, etc.) to promote mixing and agitation of runoff prior to final polishing in the sediment basin (3, 15). Flocculants cause small, suspended particles to be bond together, creating larger flocs. Larger flocs more rapidly settle from suspension, and minimize turbidity. These products may be natural or synthetic polymers. Manufacturer recommendations as well as state and local requirements should be followed to properly select a flocculant and dosage.

3. MATERIALS

Temporary sediment basins should be not exceed 1.5 m (5 ft) in depth to accommodate a standard baffle height. Baffles, or equivalent energy dissipaters, such as rip rap, should be designed to withstand high flow velocities. If baffles are used, it is recommended to employ a double layer of 700-900 g/m^2 (20.6-26.5 oz/yd^2) coconut coir material with apparent opening size of 40%. Supporting t-posts should have minimum density of 1.98 kg/m (1.33 lb/ft) (9, 10). The basin should dewater through a surface dewatering mechanism that passes through the dam with at least one anti-seep collar at the center of the dam, projecting a minimum of 0.5 m (1.5 ft). The discharge point of both the inflow channel and dewatering device shall be stabilized with rip rap or equivalent. At a minimum, the forebay and auxiliary should be lined with non-woven geotextile.

4. INSTALLATION

Sediment basins should be constructed according to the design, unless otherwise specified by the engineer of record. Coir baffles, or equivalent energy dissipater, must be installed to withstand high flow velocity. If coir baffles are used, t-posts should be erected with a maximum spacing of 1.2 m (4 ft) on center to support the first baffle in the series. Subsequent baffles should be supported by t-posts spaced no more than 3.3 m (10 ft) on center. The surface dewatering mechanism should be assembled according to manufacturer recommendations. Auxiliary spillway should be constructed on non-disturbed land. If the auxiliary spillway must be built on an earthen berm, the spillway must be lined with a geotextile. Seeding should be applied to all bare slopes. Inlet and discharge should be stabilized with vegetation, rip rap, or equivalent, to prevent erosion.

5. INSPECTION AND MAINTENANCE

Sediment basins should be inspected regularly and after significant runoff events to ensure adequate storage capacity and structural integrity. A basin should be dredged once the deposited sediment volume reaches one-third to one-half of the standing pool capacity. In addition, the excavated sump should be regularly maintained to avoid resuspensions of captured material. All dredged sediment should be disposed of properly. Sediment trapping efficiency and discharged water quality may be reduced if not properly maintained. Ensure skimmer is not clogged with sediment. Compromised structural integrity of the auxiliary spillway may result in catastrophic dam failure.

6. ACKNOWLEDGEMENTS

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